PERSULFATE BARRIER INSTALLATION REPORT AND MONITORING UPDATE

FORMER CIBA-GEIGY FACILITY
180 MILL STREET, CRANSTON, RHODE ISLAND

PREPARED FOR:

BASF

PREPARED BY:

CIVIL & ENVIRONMENTAL CONSULTANTS, INC.
LANGHORNE, PENNSYLVANIA

CEC PROJECT 172-818

DECEMBER 2020

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1.0 INTRODUCTION

The Statement of Basis (SOB[1]) [EPA, 2016] for the Proposed Remedy Determination for the Former Ciba-Geigy Facility located at 180 Mill Street, Cranston, Rhode Island (Site) specified the installation and operation of a Permeable Reactive Barrier (PRB) oriented parallel to the river bulkhead utilizing ozone generated on-Site to address the groundwater plume that has the potential to discharge to the river receptor in excess of the Site-specific Media Protection Standards (MPS).

The PRB concept is designed to destroy dissolved Compounds of Concern (COCs) in-situ, by chemical oxidation, before they migrate off-Site and discharge to the Pawtuxet River, and as such, its primary function is to replace the former pump-and-treat interim remedial measure (IRM).

The SOB specified that the PRB will be operated in a continuous fashion and regularly monitored to determine: (1) when groundwater concentrations up-gradient and down-gradient of the barrier decline to a level where monitored natural attenuation (MNA) processes must be considered as the limiting step to aquifer restoration, and (2) when impacted groundwater discharge to the river is below the Site-specific MPS. When these conditions are met, the PRB will be idled and monitoring will continue for several rounds after idling to determine whether there is a rebound in contaminant concentrations above the MPS. If there is no rebound above the MPS, then the system will be adapted to provide support to the longer-term MNA program, the details of which will be included in the Operation and Maintenance (O&M) plan to be submitted.

The SOB specified ozone gas as the PRB oxidant. However, during remedy development, BASF identified significant operation and maintenance feasibility issues relative to the ozone technology and given recent advances in PRB technology since SOB issuance, BASF identified an alternative PRB application that it considered a robust and feasible alternative. On June 10, 2019 BASF sent both the United States Environmental Protection Agency (USEPA) and Rhode Island Department of Environmental Management (RIDEM) a letter proposing the use of a solid oxidant (i.e., alkaline

[1] EPA 2016: RCRA Corrective Action Program, Statement of Basis for the Proposed Remedy Determination for the Former Ciba-Geigy Facility, May 2016.

activated potassium persulfate or AAKP) deployed in suspended ‘socks’ within an array of wells to provide a constant release, through dissolution and scheduled material replacement, of COC-destroying oxidant as impacted groundwater fluxes through the PRB. The letter outlined the need to implement field and laboratory work to provide the necessary data upon which to design and verify the effectiveness of the application. The proposed work included:

1. High-Resolution Mass Flux Profile Study (Profile Study) to characterize the primary mass-flux discharge zones that require treatment.
2. Bench-Scale treatability study of Site soils and groundwater to demonstrate method efficacy and estimate required oxidant mass loading and ancillary amendment requirements.

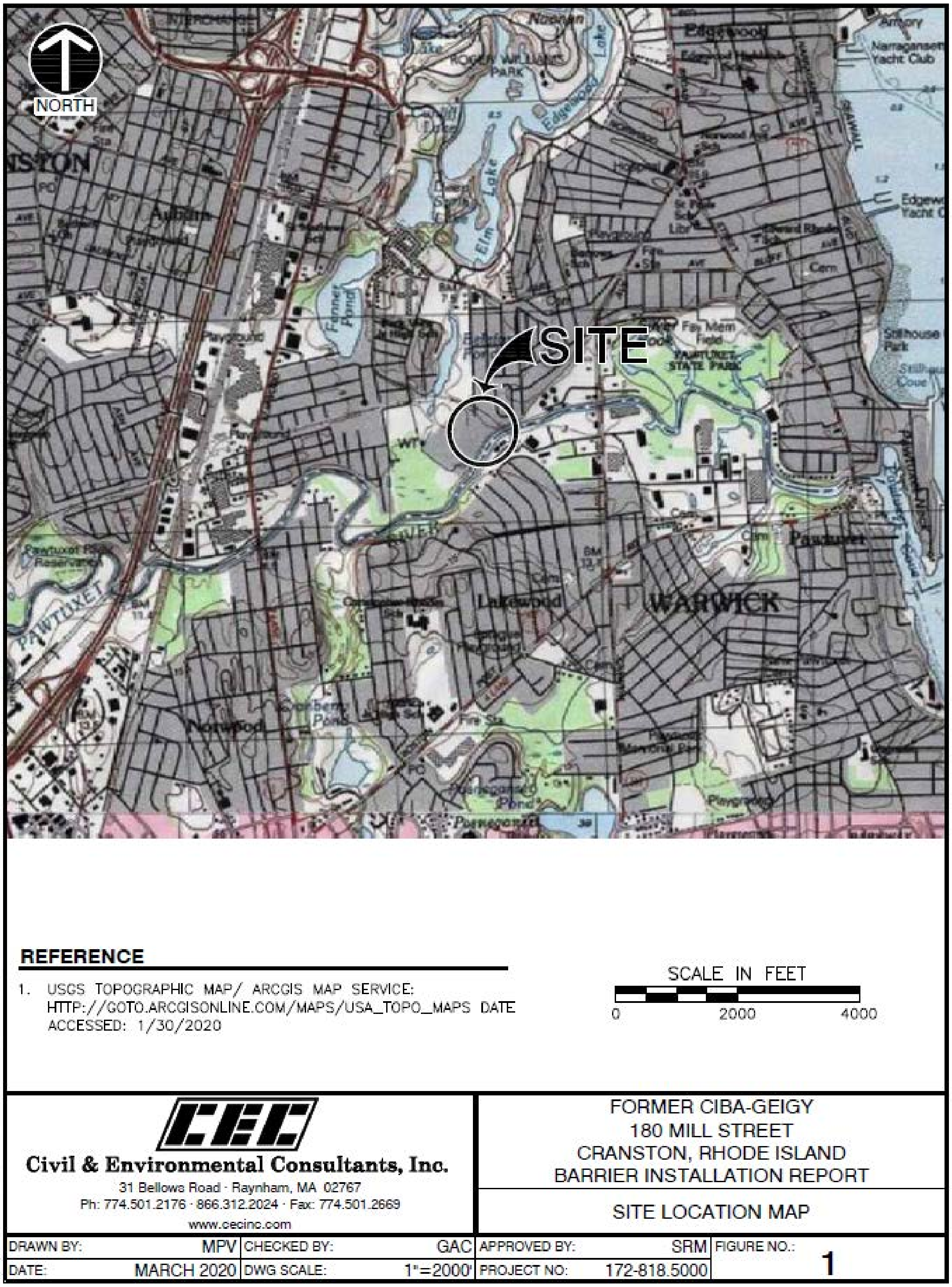
The USEPA approved the proposed change in applied oxidant and delivery method via an electronic mail correspondence to BASF and RIDEM dated July 9, 2019. A supporting work plan was submitted to the agencies on July 12, 2019. In addition to the above-described work, the work plan also included a field-scale treatability study, wherein AAKP would be deployed and monitored in existing impacted, groundwater wells.

The purpose for this report is to document BASF’s means and methods used to design, install, and monitor the groundwater remedy for the Site. To this end, this report documents the following:

1. Review and results of the Profile Study;
2. Review and results of the Field-Scale Treatability Study;
3. Review and results of the Bench-Scale Treatability Study;
4. Documentation of the installation of the in-situ treatment barrier; and
5. Documentation of the initial O&M and monitoring of the full-scale in-situ alkaline activated sodium persulfate (AAKP) barrier.

2.0 BACKGROUND

Site location is provided in **Figure 1.**



In 1995, a groundwater extraction and treatment system was installed at the Site to capture and treat water impacted above the Site-specific, MPS before the groundwater could discharge to the Pawtuxet River. The groundwater MPS were calculated as part of the 1995 RCRA Facilities Investigation (RFI) Report for the following compounds:

- 1,2-Dichlorobenzene (1,2-DCB) – 94 micrograms per liter (µg/L)
- Chlorobenzene (CB) – 1,700 µg/L;
- 2-Chlorotoluene (2-CT) – 1,500 µg/L;
- Toluene (TOL) – 1,700 µg/L; and
- Total Xylenes (XYL) – 78 µg/L.

The Supplemental Remedial Investigation Report (AECOM 2016a[2]) documented the historic IRM monitoring results and the need for additional remedial actions at the Site. Additional remedial measures were screened in the Corrective Measures Study (CMS) [AECOM 2016b[3]] including using an in-situ oxidation barrier for treatment of volatile organic compounds (VOCs) prior to potential discharge to the river.

The CMS called for use of in-situ ozone as the oxidant for the barrier; however, as previously discussed logistical challenges with ozone treatment made ozone use infeasible and an in-situ treatment barrier using AAKP deployed in an array of wells was proposed to the USEPA and RIDEM in July 2019.

[2] AECOM (2016a): Supplemental Remedial Investigation Report, Revised, April, 2016
[3] AECOM (2016b): Corrective Measures Study, Final, April 2016.

3.0 PROJECT APPROACH AND OBJECTIVES

This section presents and overview of the Profile Study, the Field-Scale Treatability Study, and the Bench-Scale Treatability Study, along with the rationale for selection of these studies to evaluate the construction of the full-scale in-situ AAKP barrier.

3.1 KEY DESIGN PARAMETERS

The predesign testing and the eventual design and operations and maintenance (O&M) of the in-situ barrier is primarily a function of the following parameters and hydrogeological attributes:

1) Barrier application area: this is the width and depth of the barrier normal to groundwater flow, where it is intended to intercept dissolved-phase concentrations of COCs above the MPS along flow paths that discharge to the river.
2) Groundwater seepage velocity: this parameter has two effects:
   a. Controls contact time with the AAKP in the barrier, where faster seepage velocities require a thicker barrier, thus allowing more groundwater/AAKP contact time.
   b. AAKP utilization, where faster seepage velocity leads to faster dissolution of AAKP.
3) Magnitude of groundwater impact: High groundwater COC concentrations will require longer contact time with the AAKP for the required degradation.
4) Aquifer properties:
   a. Soil and groundwater buffering capacity and pH: KP requires a pH greater than 10.5 to be "activated" to act as effective oxidant for all the COCs at the Site (ITRC 2005). This is accomplished by adding a calcium hydroxide (lime or $CaOH_2$) activator to the KP, thus producing what is referred to AAKP.
   b. Aquifer matrix or natural oxidant demand (NOD) and groundwater oxygen demand (GWOD): the amount of oxidizable, non-COC, components in soil and groundwater that will react with KP, thus reducing its capacity to oxidize COCs in groundwater. Given the barrier application, (NOD) is a temporary sink for KP

reactivity, where over time the KP will be continuously replenished while the NOD is oxidized and depleted. Thus, this parameter will only affect the initial effectiveness of the barrier.

3.2 PROFILE STUDY

The Profile Study was completed in July 2019 to identify the areas of the subsurface cross-section where the Site COCs are migrating towards the river. This allows for accurate placement of treatment wells containing oxidant to create the in-situ barrier and prevent COCs from reaching the river. The goals of the Profile Study were as follows:

- Accurately delineate where groundwater, impacted by Site-related COCs above the relevant MPS, is discharging to the river;
- Identify the significant mass flux zones where remedial oxidant is required and can be effectively applied;
- Estimate groundwater velocity; and
- Identify appropriate Site performance monitoring well locations and screen intervals.

3.3 BENCH-SCALE TREATABILITY STUDY

Soil and groundwater samples were collected from the Site during the Profile Study and subjected to a bench-scale AAKP treatability study, to develop design parameters for application at the Site. The goals of the Bench Study were as follows:

- Determine the NOD to which the PRB will be exposed and GWOD for the Site (oxidant scavengers);
- Determine the buffering capacity of the aquifer materials, which in addition to the seepage velocity, is used to determine the amount of the lime required to elevate the pH to activate the KP.

- Given the AAKP recipe for a given seepage velocity based on the above data, measure the effectiveness of AAKP dosing required to oxidize the Site dissolved phase COCs (including polychlorinated biphenyls [PCBs]) to below the Site-specific MPS.

3.4 FIELD-SCALE TREATABILITY STUDY

A field-scale treatability study (Field Study) involved the application of AAKP in permeable socks installed in an existing impacted monitoring well. Given water quality conditions before and during AAKP application through periodic low flow sampling, the study was intended to evaluate the ability of AAKP to both elevate the in-situ pH and treat VOCs and PCBs dissolved in groundwater.

3.5 BARRIER INSTALLATION

Given barrier dimensions derived using all available data, barrier installation was achieved in two phases. First, additional source area and aquifer characterization was conducted (aquifer probing) to further characterize stratigraphy and mass distribution, in particular DNAPL. Including these data, the second phase resulted in the installation of a barrier array intended to meet the objectives.

4.0 METHODS AND FINDINGS

This section describes the methods for development and implementation of the pre-design studies. Methods for installation of the barrier are also described.

4.1 PROFILE STUDY

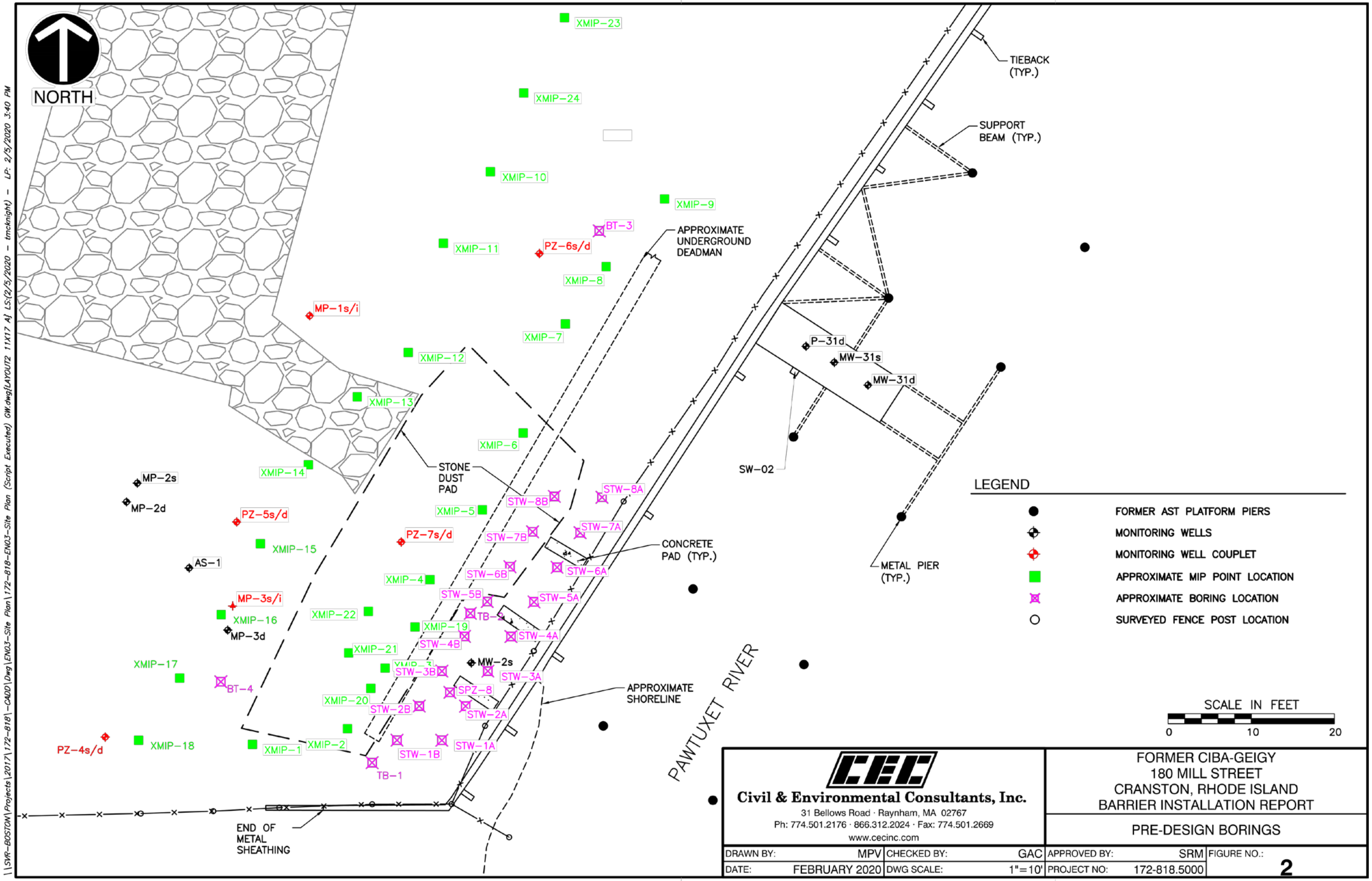
The Profile Study was completed using a Membrane Interface Probe-Hydraulic Profiling Tool (MiHpt) operated by Columbia Technologies, Inc. (Columbia). This tool is a combination of the membrane interface probe (MIP) and the hydraulic profiling tool (HPT). The MIP is a direct push, direct sensing tool used to measure and log the relative concentrations of in-situ VOCs with depth. The HPT is used to measure and log relative hydraulic permeability with depth. This combined tool is referred to as the MiHpt.

For this assessment, three laboratory grade chemical detectors were employed on the MIP: a Halogen Specific Detector (XSD™), a Photo Ionization Detector (PID) and a Flame-Ionization Detector (FID). The XSD™ was developed to address the need for a sensitive and selective detector for halogenated compounds. The MIP-XSD detects a broad spectrum of chlorinated VOCs, including the compounds of interest for this assessment. The XSD™ provides high halogen selectivity, making it an effective tool for identification and measurement of halogenated compounds in environments where other contaminants, such as hydrocarbons, are present. The MIP-XSD detector responds to halogenated compounds, including bromine, chlorine, and fluorine. The MIP-PID, with a 10.6 electron volt (eV) lamp, responds to a wide range of volatile aromatic compounds, including benzene, toluene, ethylbenzene, and xylenes (BTEX). The PID also responds well to chlorobenzene and dichlorobenzenes. The FID is a general detector useful for detecting petroleum hydrocarbons (straight and branched chain alkanes), including methane and butane as well as for confirmation of high concentrations of compounds seen on the PID and XSD.

The HPT with the Electrical Conductivity (EC) system is used to evaluate subsurface hydrostratigraphy in the area of investigation. The HPT pressure logs record changes in hydraulic pressure measured directly as water is pumped into the formation at a constant rate. These logs reveal the variability of the relative hydraulic conductivity of the soil. The EC measures the electrical conductivity of soil and groundwater. Electrical conductivity differences can be related to changes in stratigraphy, providing insight into contaminant pathways when viewed in relation to chemical detector response.

As equipped, the combined MiHpt tool provides an estimate for the primary contaminant mass flux zones (concentration times hydraulic conductivity), which is verified in the field with targeted soil and water grab sampling.

The MiHpt tool was advanced using a Geoprobe direct push type (DPT) drill rig at 24 locations (XMIP-1 through XMIP-24) that were installed in two transects (A and B) approximately 20 feet apart and parallel to the bulkhead/river. Within each transect, the MiHpt locations were installed approximately 10 feet apart. As referenced below, additional locations were added to resolve the MIP response at location XMIP-3. **Figure 2** depicts the location of the MiHpt points. The depth of each MiHpt location is provided in **Table 1**.


NORTH
XMIP-23
XMIP-24
TIEBACK (TYP.)
SUPPORT BEAM (TYP.)
XMIP-10
XMIP-9
BT-3
APPROXIMATE UNDERGROUND DEADMAN
XMIP-11
PZ-6s/d
XMIP-8
MP-1s/i
XMIP-7
XMIP-12
P-31d
MW-31s
MW-31d
XMIP-13
XMIP-6
SW-02
STONE DUST PAD
XMIP-14
MP-2s
MP-2d
PZ-5s/d
XMIP-5
STW-8B
STW-8A
STW-7A
STW-7B
PZ-7s/d
CONCRETE PAD (TYP.)
XMIP-15
AS-1
STW-6B
STW-6A
METAL PIER (TYP.)
XMIP-4
STW-5B
STW-5A
MP-3s/i
TB-2
XMIP-16
XMIP-22
XMIP-19
MP-3d
STW-4B
STW-4A
XMIP-21
MW-2s
XMIP-17
STW-3B
STW-3A
BT-4
SPZ-8
APPROXIMATE SHORELINE
XMIP-20
STW-2B
STW-2A
PAWTUXET RIVER
PZ-4s/d
XMIP-18
XMIP-1
XMIP-2
STW-1B
STW-1A
TB-1
END OF METAL SHEATHING
LEGEND
FORMER AST PLATFORM PIERS
MONITORING WELLS
MONITORING WELL COUPLET
APPROXIMATE MIP POINT LOCATION
APPROXIMATE BORING LOCATION
SURVEYED FENCE POST LOCATION
SCALE IN FEET
0
10
20
CEC
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FORMER CIBA-GEIGY
180 MILL STREET
CRANSTON, RHODE ISLAND
BARRIER INSTALLATION REPORT
PRE-DESIGN BORINGS
DRAWN BY: MPV
CHECKED BY: GAC
APPROVED BY: SRM
FIGURE NO.: 2
DATE: FEBRUARY 2020
DWG SCALE: 1"=10'
PROJECT NO: 172-818.5000

Table 1
MiHpt Location Depth Summary
Ciba-Geigy RCRA Closure Project

Location	Depth (feet bgs)	Location	Depth (feet bgs)
XMIP-1	27	XMIP-13	38
XMIP-2	40	XMIP-14	28
XMIP-3	40	XMIP-15	42
XMIP-4	43	XMIP-16	48
XMIP-5	32	XMIP-17	43
XMIP-6	28	XMIP-18	28
XMIP-7	28	XMIP-19	33
XMIP-8	28	XMIP-20	38
XMIP-9	28	XMIP-21	33
XMIP-10	32	XMIP-22	33
XMIP-11	27	XMIP-23	28
XMIP-12	27	XMIP-24	28

bgs – Below Ground Surface
Depth rounded to the nearest foot

Details regarding the methods used for and results derived from the Profile Study are provided in the Columbia Analytical Report in **Appendix A**.

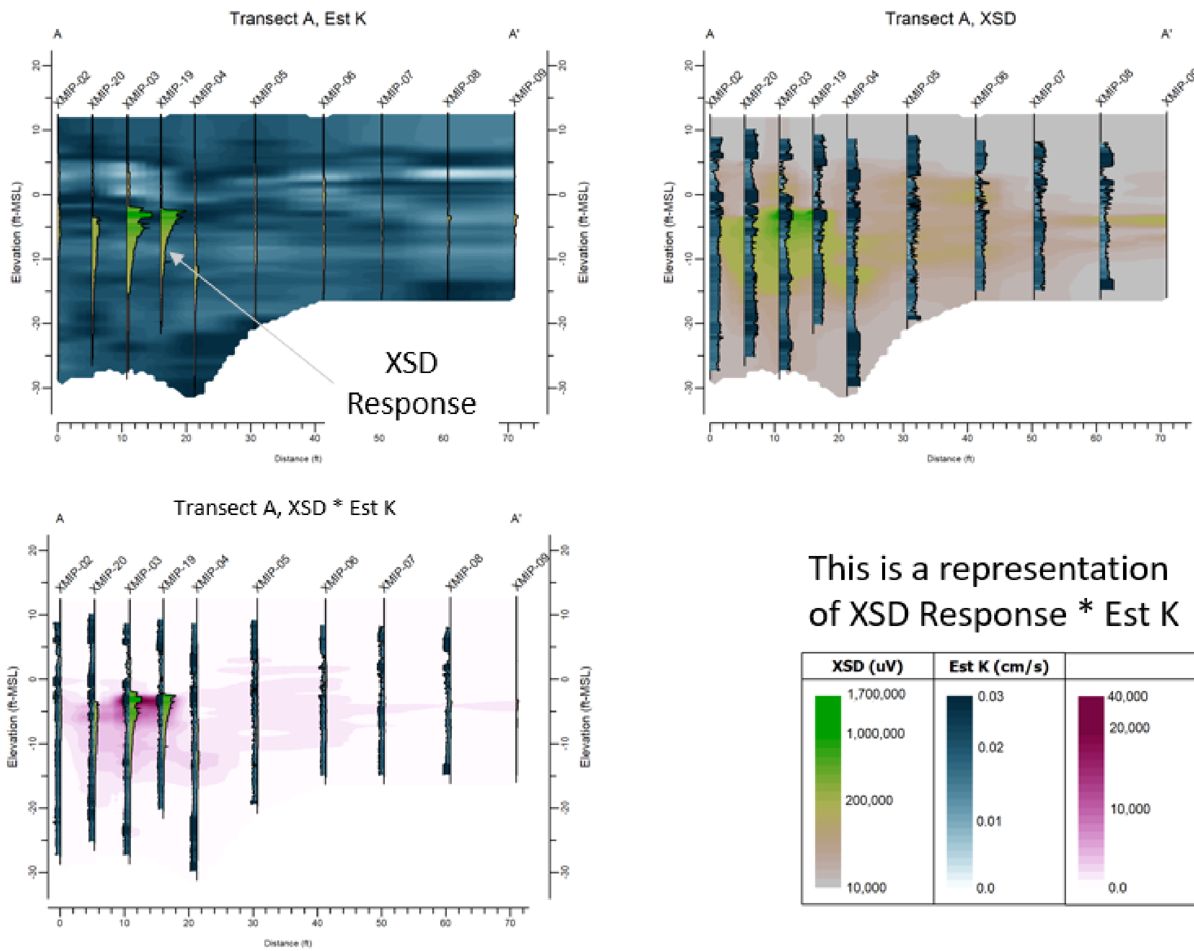
The following sub-sections provide key findings from the study that support the design of the PRB.

4.1.1 MiHpt Results

Figures 3A and 3B depict the two transect profiles of relative contaminant mass flux [M/T] based on an estimate of concentration [M/L^3] generated from the XSD detector, multiplied by an estimate of hydraulic conductivity [L/T] times unit area [L^2] generated from the HPT tool. As can be seen in **Figures 3A and 3B**, by far the highest relative mass flux is associated with locations XMIP-3 and XMIP-19 along Transect A. Given the MIP response at location XMIP-3, additional profile locations were added to the plan, locations XMIP-20, 21 and 22 (**Figure 2**), to refine the spatial extent of observed impact.

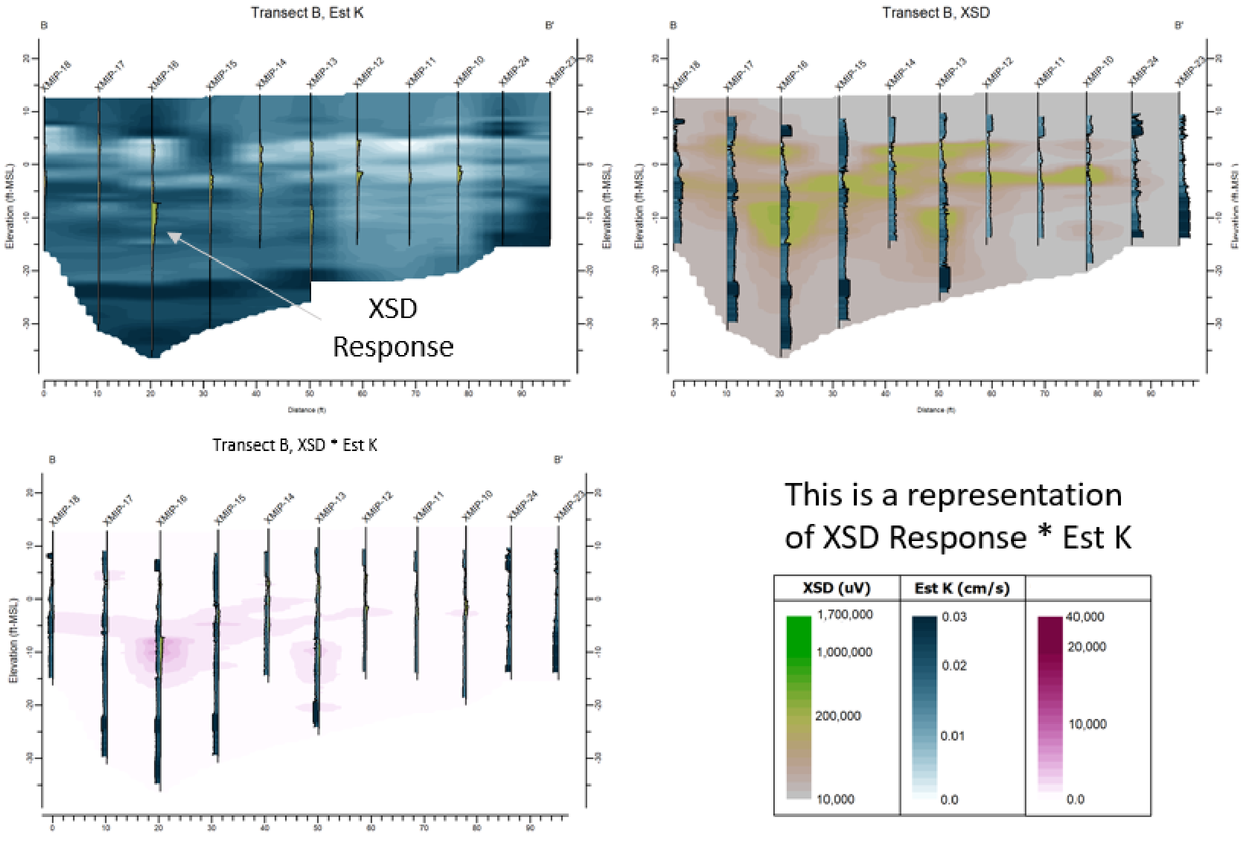
As discussed in detail below, the profile data was used to define post-MIP soil and groundwater sampling.

Figure 3A
MiHpt Study Transect A
Ciba-Geigy RCRA Closure Project



Cross-section along transect A (closer to the bulkhead) [from Figure 5 in **Appendix A**] showing the estimated K and XSD responses. The product of K and XSD responses provides an estimate of the primary mass flux zones. In this case, it is centered around XMIP-3 and 19.

Figure 3B
MiHpt Study Transect B
Ciba-Geigy RCRA Closure Project



Cross-section along transect B [from Figure 6 in **Appendix A**] showing the estimated K and XSD response along transect B. The product of K and XSD responses provides an estimate of the primary mass flux zones. The mass detected in transect A does not extend to transect B.

4.1.2 Stratigraphy and Soil and Groundwater Quality

Given the MiHpt-derived contamination, stratigraphy and hydraulic conductivity screening profiles, ground-truthing soil and groundwater sampling was conducted on July 26, 2019 and July 29, 2019 to correlate the screening data with actual stratigraphy and media impact.

Table 2 provides a summary of the soil analytical data from cores collected from XMIP-3 and XMIP-12 (these soils were subsequently used for the Bench Study, discussed in the next Section).

Table 2
Soil Sampling MPS Compounds and PCB Data Summary [mg/kg]
Ciba-Geigy RCRA Closure Project

Compound	XMIP-3 (15-18 feet bgs)	XMIP-12 (9 to 12 feet bgs)
1,2-Dichlorobenzene	3,200	11
2-Chlorotoluene	16	0.13
Chlorobenzene	130	91
Total Xylene	4.5 U	0.85
Toluene	3	0.44
PCB total	980	2.3

bgs – Below Ground Surface
Depth rounded to the nearest foot
U - Analyte not detected at Method Detection Limit (MDL)
All concentrations in milligrams per kilogram (mg/kg)

Of particular importance with respect to PRB design, based on the HPT data and following cores at locations XMIP-3 and XMIP-12, there is an extensive coarse granular layer at 14 to 17 feet bgs[4]. This layer is bounded above and below by fine silty and sandy material. Liquid DNAPL is observed at XMIP-3 at the base of this unit, bound to the west (upland side) by XMIP-21 and 22, to the north (downstream side) by XMIP-4, and the south (upstream side) by XMIP-20. The DNAPL consists primarily of mono- and di-chlorobenzene with PCB present (**Table 2**). It is noted that the composition and magnitude of the VOCs observed at XMIP-03 is remarkably different from that at XMIP-12, where 1,2-DCB and PCB dominate at XMIP-03 and CB dominates at XMIP-12 with marginal PCB.

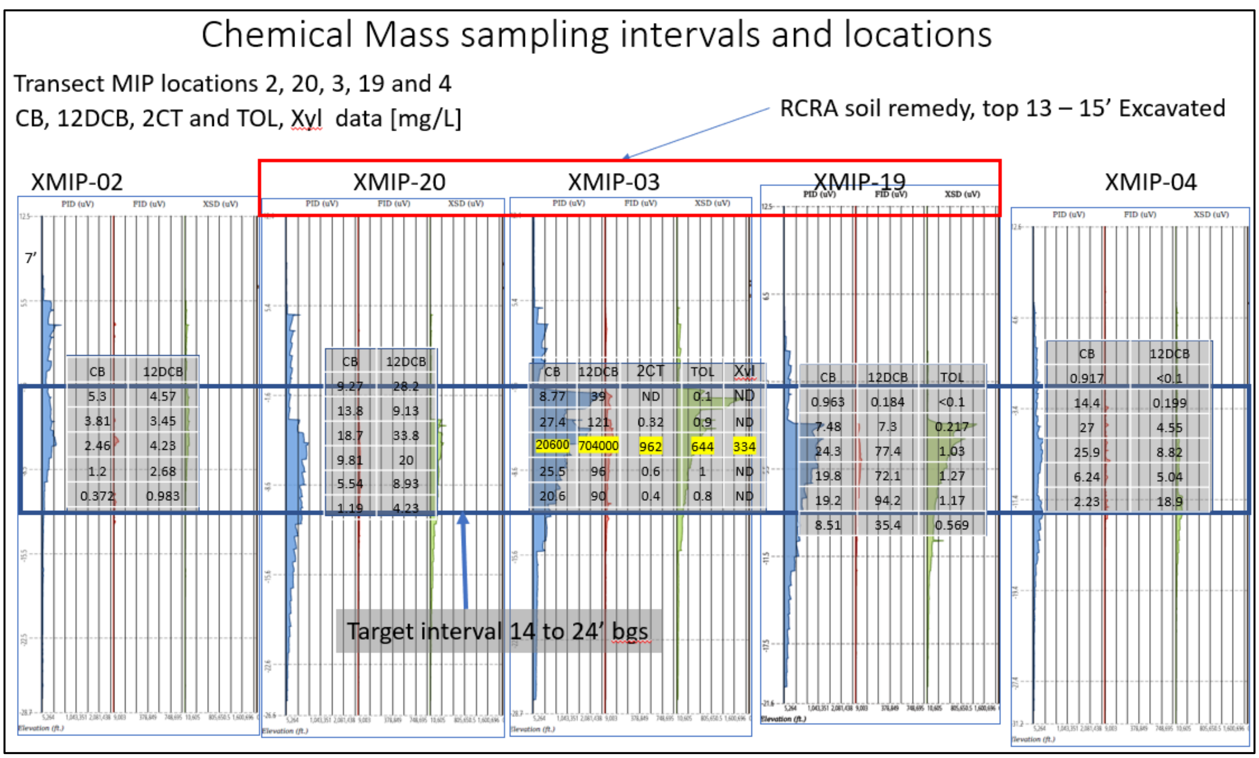
The XMIP-03 composition and location are consistent with the operation of the former Jet Sump that was housed in Building 16 and was known to have been compromised at some time in the past (AECOM, 2016a). Residual staining extends further than DNAPL indicators, where all recovered

[4] Additional subsurface characterization supporting this statement was subsequently conducted during a focused boring program to support PRB placement downgradient of the MiHpt transects, reported in Section 5.

cores exhibit a black staining. Concentration magnitude and staining decreases with distance from XMIP-3. According to anecdotal information, the Jet Sump condensate liquid contained process solvents (predominately mono and dichlorobenzene) along with the condensate water which was black with process residue. The occurrence of PCBs can be attributed to the use of PCB-containing heat-transfer oil.

Table 3 provides groundwater quality grab sample data collected at discrete intervals from 12 feet to 24 feet bgs, at locations XMIP-2, -3, -4, -19 and -20. **Figure 4** provides a cross-section spanning these locations and shows the primary MPS compounds by concentration. The samples were collected by advancing GeoProbe tooling equipped with a two-foot long screen to the target depth. Dedicated tubing was threaded through the Geoprobe rods to the center of the screened interval to withdraw groundwater using a peristaltic pump.

Figure 4
MiHpt Study Groundwater Sampling Cross-Section
Ciba-Geigy RCRA Closure Project



Cross-section where groundwater samples were collected showing the groundwater grab data (2-foot intervals) for select MPS compounds [mg/L] superimposed on the MIP response (groundwater data is provided in Table 3). Note that the highlighted data are not dissolved-phase concentrations as the sample inadvertently contained DNAPL. Note that locations 3, 19 and 20 are coincident with an area of previous RCRA soil excavation where the native soil was replaced with clean fill. Note that in general the tailing effect seen after an increase in response is due to residual mass in the trunk line that connects the MIP probe to the detector machines (technology artifact). Note that the primary components on a mass basis are 1,2-DCB and CB, and that XMIP-03, -19 and -20 are dominated by 1,2-DCB, while XMIP-04 is dominated by CB.

Samples were collected from each location at two-foot intervals, starting at approximately 12 feet bgs and extending to 24 feet bgs. Due to little to no recharge, samples at the 12 to 14 foot interval for XMIP-2 and XMIP-3 could not be collected. Each groundwater sample was slowly pumped into the appropriate, preserved laboratory provided glassware and submitted to ESS Laboratories, Inc. of Cranston, Rhode Island (ESS) and under a Chain of Custody for VOC analysis using USEPA Method 8260.

4.1.2.1 Supplemental Soil Characterization

Given the soil and groundwater data described above, it is clear that the profile work identified a source zone not previously characterized and down-gradient of XMIP-3. Because the PRB design is intended to treat impacted groundwater that is migrating from the Site, understanding the nature and extent of source material that is affecting the target groundwater is important to locating the PRB. This sub-Section summarizes additional soil data to characterize the subsurface structure and the extent of the soil impact between MiHpt profile transect A and the bulkhead. The scope of the characterization effort included the installation of 16 borings and collection of soil data for VOCs and PCBs. Probe locations, STW-1A/B through STW-8A/B, are shown in **Figure 2**.

CEC and Drillex Environmental mobilized to the Site on August 30, 2019 through September 4, 2019 to advance soil borings, evaluate the stratigraphy and DNAPL extent based on the results of the Profile Study. The boring logs are provided in **Appendix E**. The 2- to 3-foot coarse-grain layer was observed in all borings. DNAPL was visually identified in the following borings located directly down-gradient of XMIP-3:

- STW-2A at 15 to 17 feet bgs;
- STW-2B at 15 to 17 feet bgs;
- STW-3B at 16 to 18 feet bgs

Residual NAPL was visually apparent at the following locations (note low PID values in **Appendix E**).

- STW-6B at 14 to 18 feet bgs.
- STW-7B at 14 to 18 feet bgs.

Figure 5 depicts the extent of NAPL in soil and **Table 4** below identifies the depth of each soil boring, depth of soil samples collected, and analysis completed on the soil samples.

Table 3
Groundwater Grab Sample Data Summary
Ciba-Geigy RCRA Closure Project

VOCs (ug/L)											
1,2-Dichlorobenzene	**4,570**		**3,450**		**4,230**		**2,680**		**983**		94
2-Chlorotoluene	100	U	100	U	100	U	100	U	100	U	1,500
Chlorobenzene	**5,300**		**3,810**		**2,460**		1,200		372		1,700
Toluene	100	U	100	U	100	U	100	U	100	U	1,700
Xylene O	**100**	**U**	**100**	**U**	**100**	**U**	**100**	**U**	**100**	**U**	78
Xylene P,M	**200**	**U**	**200**	**U**	**200**	**U**	**200**	**U**	**200**	**U**	78
*Total Xylenes	**300**	**U**	**300**	**U**	**300**	**U**	**300**	**U**	**300**	**U**	78
Sample Name	**XMIP-3**										**Media Protection Standards (MPS)**
Depth Below Grade Surface (feet)	**14-16**		**16-18**		**18-20[a]**		**20-22**		**22-24**		
Sample Date	**07/29/2019**		**07/29/2019**		**07/29/2019**		**07/29/2019**		**07/29/2019**		
Laboratory Sample ID:	**19G0893-01**		**19G0893-02**		**19G0893-03**		**19G0893-04**		**19G0893-05**		
VOCs (ug/L)											
1,2-Dichlorobenzene	**38,600**		**121,000**		**704,000,000**		**95,500**		**90,300**		94
2-Chlorotoluene	100	U	390		**962,000**		589		404		1,500
Chlorobenzene	**8,770**		**27,400**		**20,600,000**		**25,500**		**20,600**		1,700
Toluene	130		905		**644,000**		982		792		1,700
Xylene O	**100**	**U**	**100**	**U**	**99,800**		**100**	**U**	**100**	**U**	78
Xylene P,M	**200**	**U**	**200**	**U**	**234,000**		**200**	**U**	**200**	**U**	78
*Total Xylenes	**300**	**U**	**300**	**U**	**333,800**		**300**	**U**	**300**	**U**	78

Notes:
a - The sample bottle contained free product and the data are not representative of groundwater
VOCs = Volatile organic compounds
ug/L = Micrograms per liter
Bold = Analytes above RI DEM GB Objectives and/or MPS
U = Analytes below laboratory method detection limits
* Sum of O, P&M Xylene. Non Detect are not included in the total.
Location XMIP-3 inadvertently contain DNAPL and results are not considered dissolved
Trip Blank Data for 7/29/19 is non-detect.

Table 3

Groundwater Grab Sample Data Summary

Ciba-Geigy RCRA Closure Project

Sample Name	XMIP-4												Media Protection Standards (MPS)
Depth Below Grade Surface (feet)	12-14		14-16		16-18		18-20		20-22		22-24		
Sample Date	07/26/2019		07/26/2019		07/26/2019		07/26/2019		07/26/2019		07/26/2019		
Laboratory Sample ID:	19G0852-01		19G0852-02		19G0852-03		19G0852-04		19G0852-05		19G0852-06		
VOCs (ug/L)													
1,2-Dichlorobenzene	**100**	**U**	**199**		**4,550**		**8,820**		**5,040**		**18,900**		94
2-Chlorotoluene	100	U	138		388		513		267		100	U	1,500
Chlorobenzene	917		**14,400**		**27,000**		**25,900**		**6,240**		**2,230**		1,700
Toluene	100	U	100	U	100	U	106		100	U	100	U	1,700
Xylene O	**100**	**U**	**100**	**U**	**100**	**U**	**100**	**U**	**100**	**U**	**100**	**U**	78
Xylene P,M	**200**	**U**	**200**	**U**	**200**	**U**	**200**	**U**	**200**	**U**	**200**	**U**	78
*Total Xylenes	**300**	**U**	**300**	**U**	**300**	**U**	**300**	**U**	**300**	**U**	**300**	**U**	78
Sample Name	XMIP-19												Media Protection Standards (MPS)
Depth Below Grade Surface (feet)	12-14		14-16		16-18		18-20		20-22		22-24		
Sample Date	07/26/2019		07/26/2019		07/26/2019		07/26/2019		07/26/2019		07/26/2019		
Laboratory Sample ID:	19G0852-07		19G0852-08		19G0852-09		19G0852-10		19G0852-11		19G0852-12		
VOCs (ug/L)													
1,2-Dichlorobenzene	**184**		**7,300**		**77,400**		**72,100**		**94,200**		**35,400**		94
2-Chlorotoluene	100	U	100	U	100	U	100	U	100	U	100	U	1,500
Chlorobenzene	963		**7,480**		**24,300**		**19,800**		**19,200**		**8,510**		1,700
Toluene	100	U	217		1,030		1,270		1,170		569		1,700
Xylene O	**100**	**U**	**100**	**U**	**100**	**U**	**100**	**U**	**100**	**U**	**100**	**U**	78
Xylene P,M	**200**	**U**	**200**	**U**	**200**	**U**	**200**	**U**	**200**	**U**	**200**	**U**	78
*Total Xylenes	**300**	**U**	**300**	**U**	**300**	**U**	**300**	**U**	**300**	**U**	**300**	**U**	78

Notes:

VOCs = Volatile organic compounds

ug/L = Micrograms per liter

Bold = Analytes above RI DEM GB Objectives and/or MPS

"<" = Analytes below laboratory detection limits

* Sum of O, P&M Xylene. Non Detect are not included in the total.

Trip Blank Data for 7/29/19 is non-detect.

Table 3

Groundwater Grab Sample Data Summary

Ciba-Geigy RCRA Closure Project

Sample Name	XMIP-20												Media Protection Standards (MPS)
Depth Below Grade Surface (feet)	12-14		14-16		16-18		18-20		20-22		22-24		
Sample Date	07/29/2019		07/29/2019		7/29/2019		07/29/2019		07/29/2019		07/29/2019		
Laboratory Sample ID:	19G0893-06		19G0893-07		19G0893-08		19G0893-09		19G0893-10		19G0893-11		
VOCs (ug/L)													
1,2-Dichlorobenzene	**28,200**		**9,130**		**33,800**		**20,000**		**8,930**		**4,230**		94
2-Chlorotoluene	100	U	173		324		226		100	U	100	U	1,500
Chlorobenzene	**9,270**		**13,800**		**18,700**		**9,810**		**5,540**		1,190		1,700
Toluene	232		100	U	100	U	100	U	100	U	100	U	1,700
Xylene O	**100**	**U**	**100**	**U**	**100**	**U**	**100**	**U**	**100**	**U**	**100**	**U**	78
Xylene P,M	**200**	**U**	**200**	**U**	**200**	**U**	**200**	**U**	**200**	**U**	**200**	**U**	78
*Total Xylenes	**300**	**U**	**300**	**U**	**300**	**U**	**300**	**U**	**300**	**U**	**300**	**U**	78

Notes:

VOCs = Volatile organic compounds

ug/L = Micrograms per liter

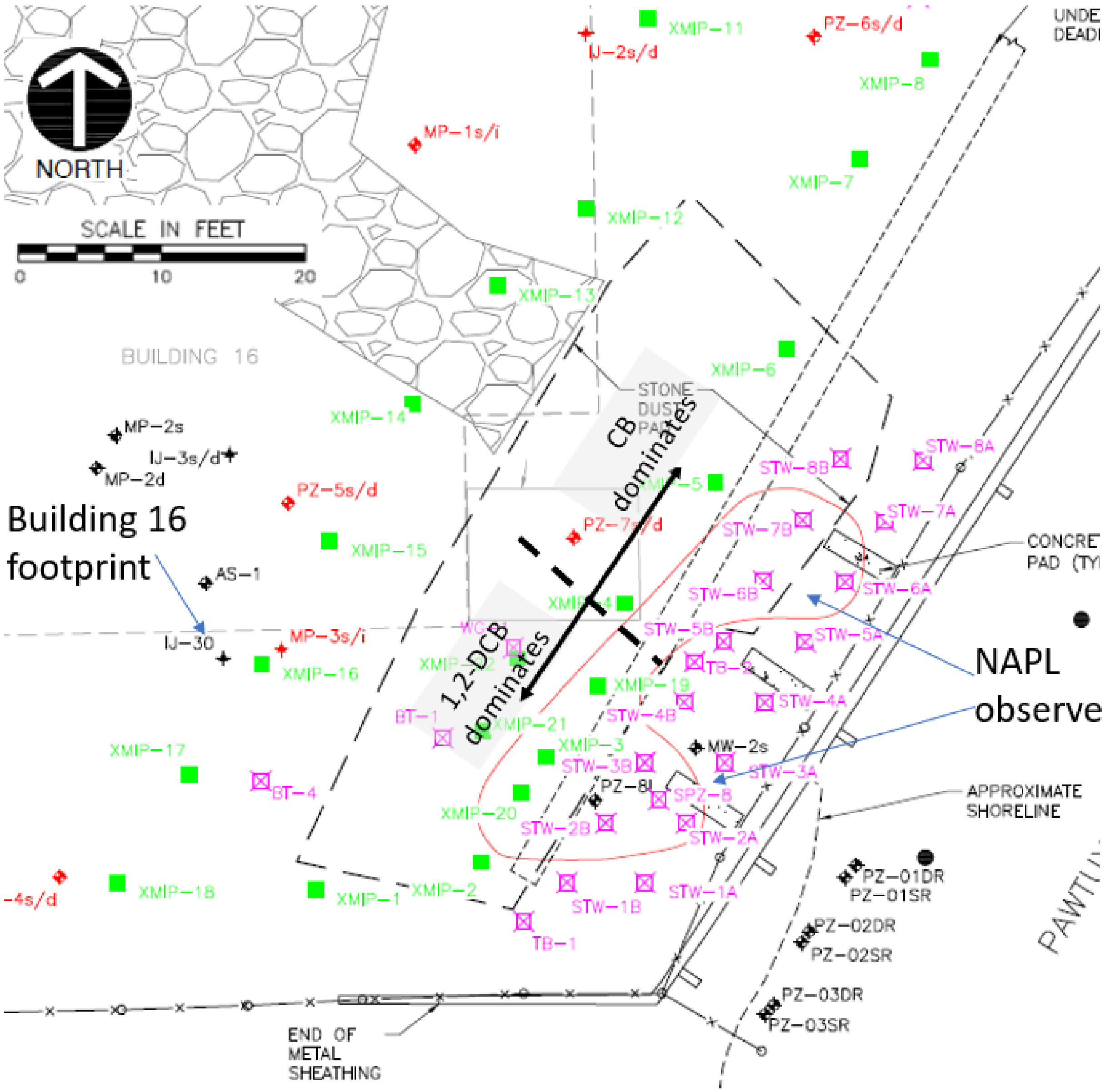
Bold = Analytes above USEPA Drinking Water MCL or MPS

"<" = Analytes below laboratory detection limits

* Sum of O, P&M Xylene. Non Detect are not included in the total.

Trip Blank Data for 7/29/19 is non-detect.

Figure 5
Extent of NAPL in Soil
Ciba-Geigy RCRA Closure Project



Borings with observed impacts indicative of the presence of NAPL. The measured impact is primarily composed of 1,2-DCB and CB, and the figure provides the spatial transition of the dominant compound. This observation is consistent with the data and interpretation provided in AECOM (2016a) [see also **Figures 6, 7, 8 and 9**].

Table 4
Soil Boring and Soil Sampling Details
Ciba-Geigy RCRA Closure Project

Boring	Depth (Feet bgs)	Sampling Interval (feet bgs)	Analysis
STW-1A	30	15 – 17	VOCs, PCBs
		20 – 25	VOCs
STW-1B	30	15 – 17	VOCs, PCBs
		20 – 25	VOCs
STW-2A	20	None	None
STW-2B	20	None	None
STW-3A	20	15 – 17	VOCs, PCBs
		19 - 20	VOCs
STW-3B	18	None	None
STW-4A	17	16 – 18	VOCs, PCBs
STW-4B	25	15 – 17	VOCs, PCBs
STW-5A	18	14 – 16	VOCs, PCBs
STW-5B	18	14 – 16	VOCs, PCBs
STW-6A	18	14 – 16	VOCs, PCBs
STW-6B	18	None	None
STW-7A	18	14 – 16	VOCs, PCBs
STW-7B	18	None	None
STW-8A	18	14 – 16	VOCs, PCBs
STW-8B	18	None	None
SPZ-8	20	None	None

Note:

VOC Analysis completed using USEPA Method 8260C
PCB Analysis completed using USEPA Method 8082

A total of 13 soil samples were analyzed for VOCs and 10 samples analyzed for PCB Aroclors and the analytical results are provided in **Table 5**.

If DNAPL was observed in the coarse sand target-sampling interval of 14 to 17 feet bgs, a soil sample of the sandy layer was not collected. In addition, the soil boring locations with DNAPL were not extended through the silty layer to prevent potential DNAPL migration. Consistent with previously collected soil data, the primary COCs on a mass basis are 1,2-DCB and CB (both less than 100 mg/kg), and these compounds were co-located with PCB Aroclors.

Table 5
Soil Sampling Analytical Data
Ciba-Geigy RCRA Closure Project

Sample Name	**STW-1A**		**STW-1A**		**STW-1B**		**STW-1B**		**STW-3A**		**STW-3A**	
Sample Depth (feet)	**15-17**		**20-25**		**15-17**		**20-25**		**15-17**		**19-20**	
Sample Date	**08/30/2019**		**08/30/2019**		**08/30/2019**		**08/30/2019**		**09/03/2019**		**09/03/2019**	
PID Reading (ppmv):	**0.9**		**0.0**		**1.4**		**0.0**		**6.9**		**12.1**	
Laboratory Sample ID:	**19I0275-01**		**19I0275-02**		**19I0275-03**		**19I0275-04**		**19I0275-05**		**19I0275-06**	
VOCs (mg/kg)												
1,2-Dichlorobenzene	**0.0415**	**J**	**0.0492**	**J**	**0.245**		**0.0723**	**J**	**0.100**	**J**	**12.6**	
2-Chlorotoluene	0.159	U	0.182	U	**0.0237**	**J**	0.185	U	**0.0197**	**J**	**0.021**	**J**
Chlorobenzene	**0.872**		0.182	U	**2.43**		**0.386**		**2.39**		**24.4**	
Toluene	0.159	U	0.182	U	**0.0947**	**J**	**0.0334**	**J**	**0.064**	**J**	0.175	U
Xylene O	0.159	U	0.182	U	0.158	U	0.185	U	0.164	U	**0.0246**	**J**
Xylene P,M	0.319	U	0.365	U	**0.0331**	**J**	0.371	U	0.328	U	0.351	U
Total Xylene	0.319	U	0.365	U	**0.0331**	**J**	0.371	U	0.328	U	**0.0246**	**J**
PCBs (mg/kg)												
Aroclor 1016	0.06	U	-		0.06	U	-		0.06	U	-	
Aroclor 1221	0.06	U	-		0.06	U	-		0.06	U	-	
Aroclor 1232	0.06	U	-		0.06	U	-		0.06	U	-	
Aroclor 1242	0.06	U	-		0.06	U	-		0.06	U	-	
Aroclor 1248	0.06	U	-		**1.6**		-		**0.4**		-	
Aroclor 1254	0.06	U	-		0.06	U	-		0.06	U	-	
Aroclor 1260	0.06	U	-		0.06	U	-		0.06	U	-	
Aroclor 1262	0.06	U	-		0.06	U	-		0.06	U	-	
Aroclor 1268	0.06	U	-		0.06	U	-		0.06	U	-	

Notes:
VOCs = volatile organic compounds; PCBs = Polychlorinated biphenyl; PID = photoionization detector, ppmv = parts per million by volume
mg/kg = milligrams per kilograms
Only selected MPS (Media Protection Standards) are reported
U = Analytes below laboratory method detection limits
Total Xylenes = Sum of O, P&M Xylene.
Bold = Detected above the Method Detection Limit (MDL)
J = estimated value below the MDL but above the RL

Table 5

Soil Sampling Analytical Data

Ciba-Geigy RCRA Closure Project

STW-4A	**STW-4B**	**STW-5A**	**STW-5B**	**STW-6A**	**STW-7A**	**STW-8A**
16-18	**15-17**	**14-16**	**14-16**	**14-16**	**14-16**	**14-16**
09/03/2019	**09/03/2019**	**09/03/2019**	**09/03/2019**	**09/03/2019**	**09/04/2019**	**09/04/2019**
23.7	**14.2**	**50.3**	**151**	**10.4**	**NT**	**21.1**
19I0275-09	**19I0275-11**	**19I0275-10**	**19I0275-08**	**19I0275-07**	**19I0275-12**	**19I0275-13**
3.66	**0.286**	**11.1**	**47.2**	**0.535**	**1.88**	**0.422**
0.264	**0.644**	**5.74**	**3.14**	**0.53**	0.115 U	0.130 U
6.68	**11.7**	**61.5**	**83.6**	**24.2**	**2.84**	**2.67**
0.086 J	0.144 U	**0.0445 J**	**0.249**	0.138 U	**0.315**	**0.229**
0.0422 J	**0.0231 J**	**0.164 J**	**0.136 J**	**0.176**	**0.559**	**0.155**
0.0688 J	0.289 U	0.556 U	**0.105 J**	**0.242 J**	**1.06**	**0.307**
0.0688 J	**0.0231 J**	**0.164 J**	**0.241 J**	**0.418 J**	**1.619**	**0.462**
0.06 U	0.06 U	0.07 U	12.60 U	0.06 U	0.05 U	0.06 U
0.06 U	0.06 U	0.07 U	12.60 U	0.06 U	0.05 U	0.06 U
0.06 U	0.06 U	0.07 U	12.60 U	0.06 U	0.05 U	0.06 U
0.06 U	0.06 U	0.07 U	12.60 U	**1.8** U	**1.7**	0.06 U
0.6	**3.8**	**0.8**	**203**	0.06	0.05 U	**3.4**
0.06 U	0.06 U	0.07 U	12.60 U	0.06 U	0.05 U	0.06 U
0.06 U	0.06 U	0.07 U	12.60 U	0.06 U	0.05 U	0.06 U
0.06 U	0.06 U	0.07 U	12.60 U	0.06 U	0.05 U	0.06 U
0.06 U	0.06 U	0.07 U	12.60 U	0.06 U	0.05 U	0.06 U

Notes:

VOCs = volatile organic compounds; PCBs = Polychlorinated biphenyl; PID = photoionization detector, ppmv = parts per million by volume

mg/kg = milligrams per kilograms

Only selected MPS (Media Protection Standards) are reported

U = Analytes below laboratory method detection limits

Total Xylenes = Sum of O, P&M Xylene.

Bold = Detected above the Method Detection Limit (MDL)

J = estimated value below the MDL but above the RL

4.1.3 Hydraulic Conductivity Estimate

The HPT provides an estimate of hydraulic conductivity as the tool is advanced through the subsurface. The estimated hydraulic conductivity for each MiHpt location is found in the Columbia Report in **Appendix A**. A layer of higher conductivity (estimated 0.02 cm/sec) is associated with the extensive coarse sand layer observed at 14 to 17 feet bgs. The estimated conductivity of the strata below this layer varies, but generally ranges from negligible [clay] to 0.03 cm/sec [sand] (75 feet/day). This range is quantified with actual field measurements collected historically and as part of this investigation (discussed in **Section 5.3**).

4.1.4 Profile Study Conclusions

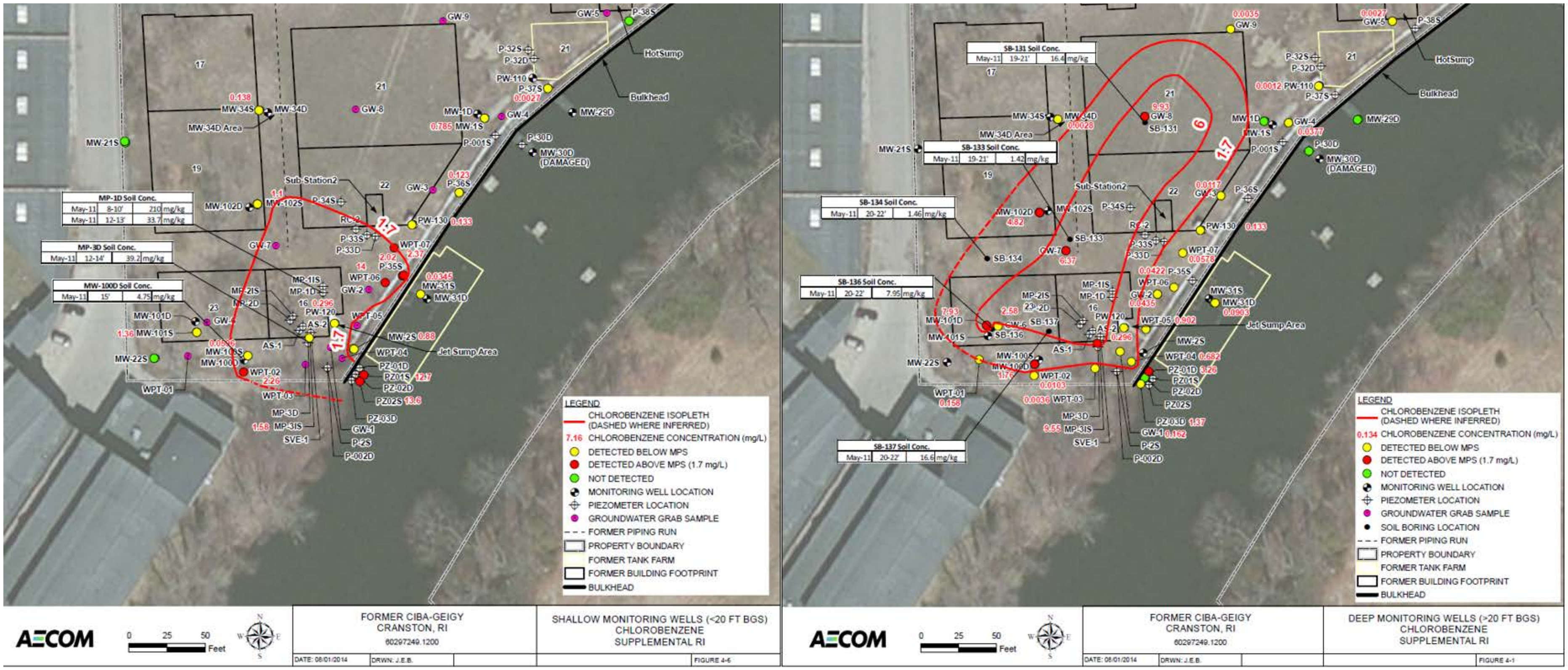
Source material in the form of DNAPL is present in a confined stratigraphic horizon that is approximately 14 to 17 feet bgs and centered at and down-gradient of XMIP-3. Its location is consistent with the Site's historical record (plant operations [Jet Sump failure] and soil and groundwater database). On a mass basis, the primarily COCs are 1,2-DCB and CB, where 1,2-DCB dominates the mixture in the immediate vicinity of XMIP-03. **Figures 6, 7, 8 and 9** provide the groundwater characterization for these compounds as determined from the SSRI (AECOM 2016a) and CMS (AECOM 2016b). This characterization is consistent with the data collected as the result of this investigation.

The data support the following PRB design area normal to groundwater flow:

1. Total depth: As per data provided in AECOM (2016a), upland groundwater flow is controlled by the river and the bulkhead, where groundwater is deflected downward by the bulkhead as it migrates toward the river discharge point (this characterization is further assessed/refined based on the PRB well network, described in **Section 5.3**). Therefore, the depth of the PRB must extend several feet past the depth of the bulkhead.

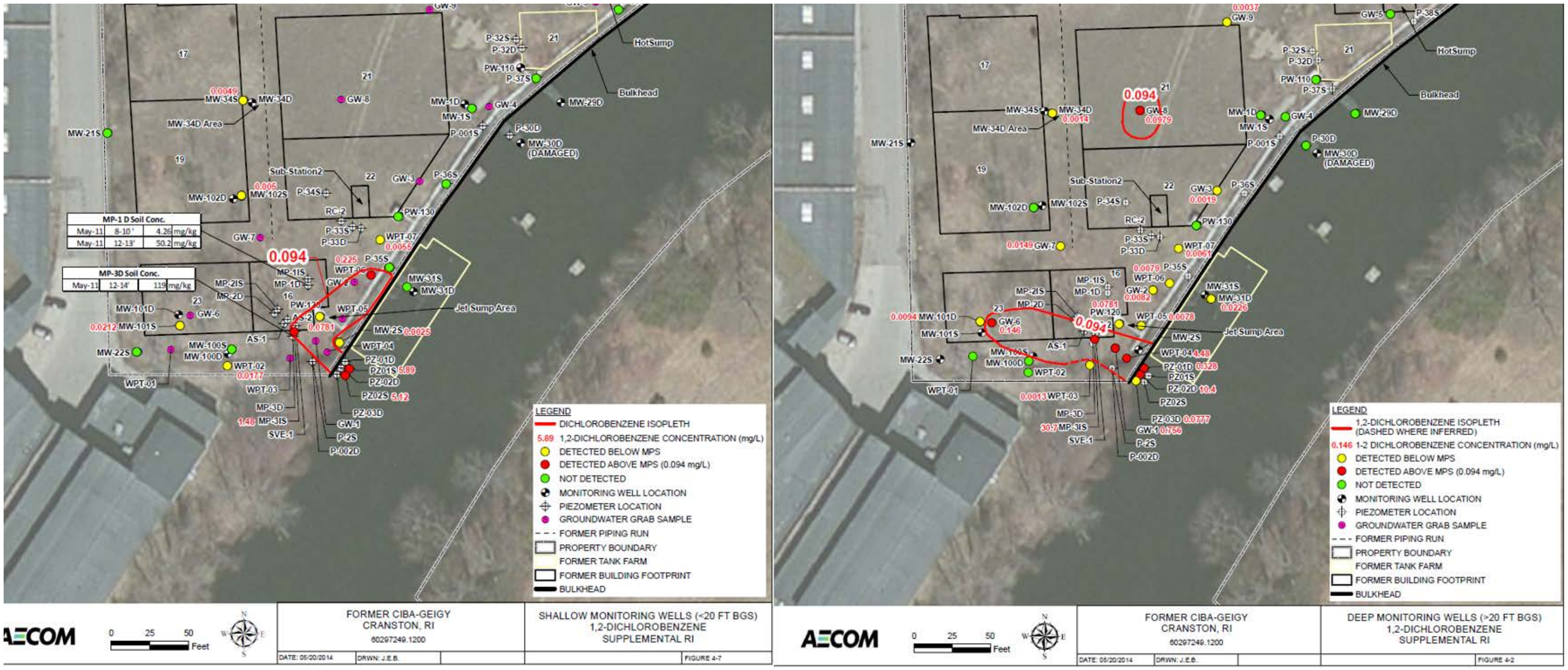
2. Given the presence of DNAPL observed to approximately 20 feet bgs, the PRB should begin at approximately 22 feet bgs to avoid source material while at the same time intercepting impacted groundwater. This depth interval is consistent with the profile data collected during AECOM (2016) (see Figures 8 and 9).
3. PRB length normal to groundwater flow: The length of impact is approximated by the 1,2-DCB plume shown in **Figures 7** and **9** below. This plume is centered around the characterized impact associated with the Jet Sump, and there appears to be a preferential flow path connecting the upland and river hydrologic regimes.

Figure 6
Groundwater Chlorobenzene Results from 2016 Supplemental Remedial Investigation
Ciba-Geigy RCRA Closure Project



Dissolved-phase chlorobenzene in excess of MPS in shallow (<20’ bgs) and deep (>20’) groundwater. Copied from the SSRI (AECOM 2016a), Figures 4-1 and 4-6.

Figure 7
Groundwater 1,2-Dichlorobenzene Results from 2016 Supplemental Remedial Investigation
Ciba-Geigy RCRA Closure Project

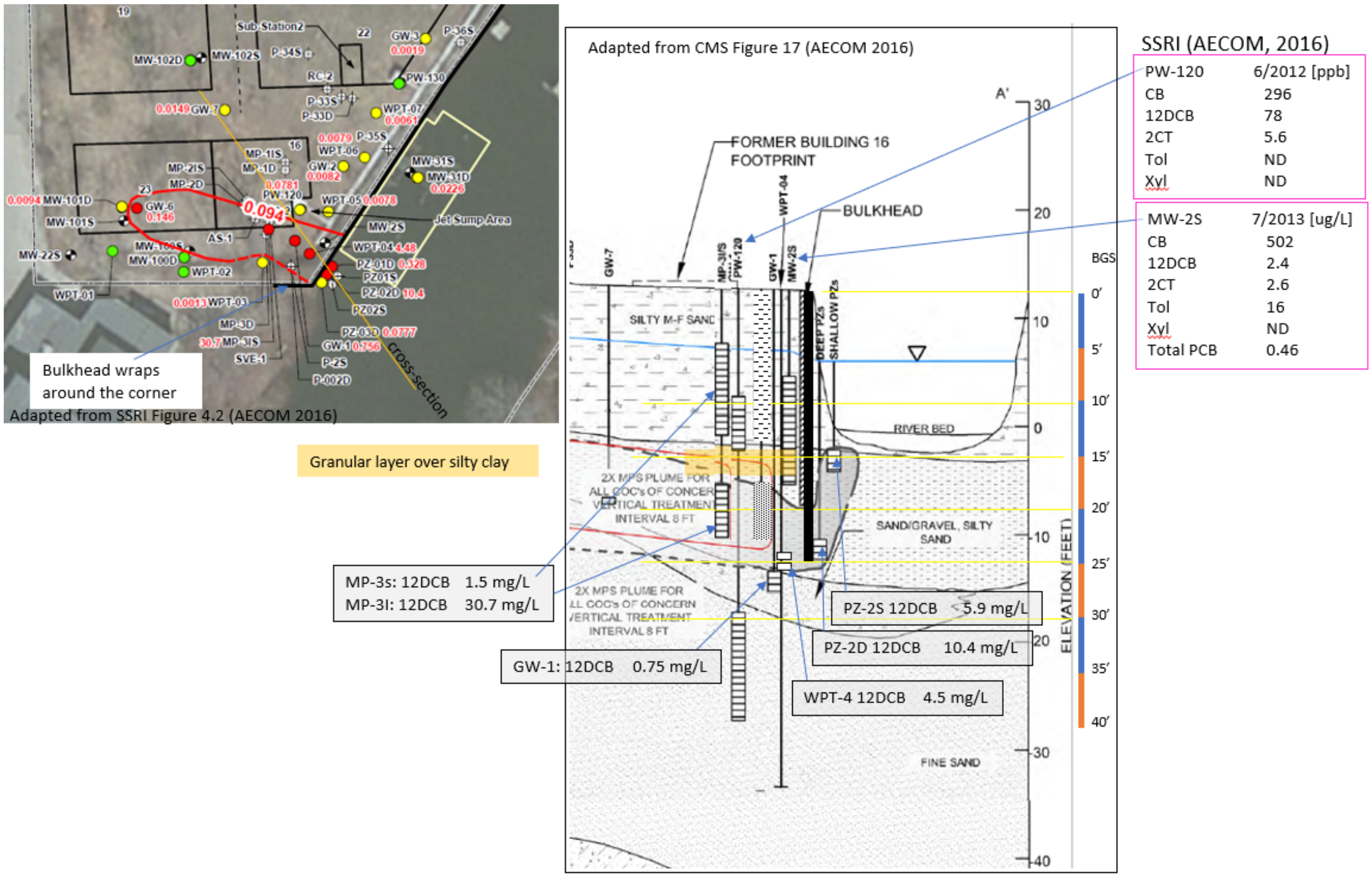


Dissolved-phase 1,2-dichlorobenzene in excess of MPS in shallow (<20' bgs) and deep (>20') groundwater. Adapted from the SSRI (AECOM 2016a), Figures 4-2 and 4-7.

Figure 8

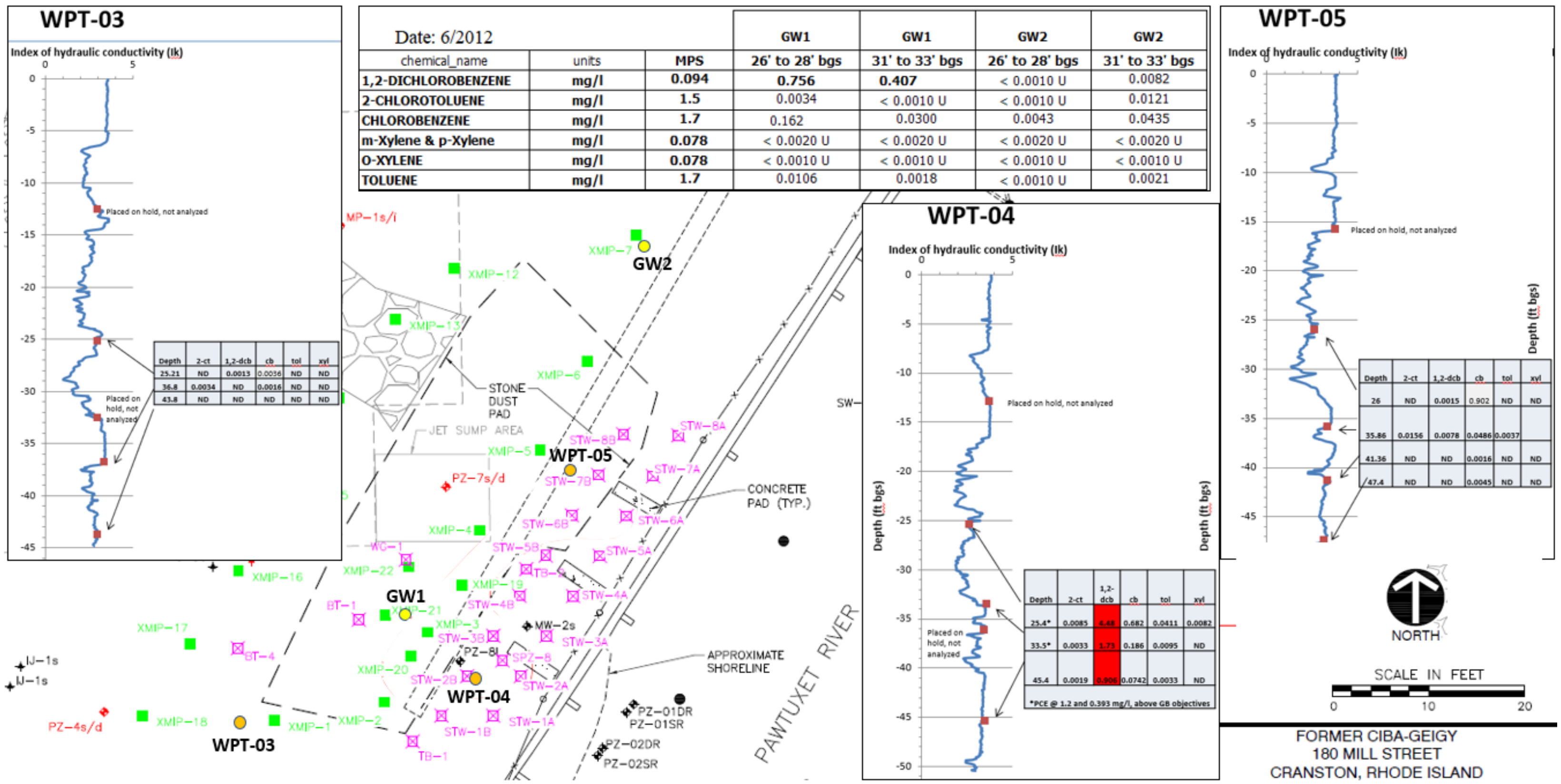
Groundwater 1,2-Dichlorobenzene Results and Cross Section from the 2016 Supplemental Remedial Investigation

Ciba-Geigy RCRA Closure Project



CSM cross-section adapted from CMS Figure 17 (AECOM 2016b). Graphic shows dissolved phase 12DCB migration from the apparent source area (jet sump) towards the river (discharging groundwater). The presence of the bulkhead deflects groundwater vertically to >25' bgs before it discharges to the river hydrological system.

Figure 9
Supplemental Groundwater Data from the 2016 Remedial Investigation Report
Ciba-Geigy RCRA Closure Project



Date: 6/2012			GW1	GW1	GW2	GW2
chemical_name	units	MPS	26' to 28' bgs	31' to 33' bgs	26' to 28' bgs	31' to 33' bgs
1,2-DICHLOROBENZENE	mg/l	0.094	0.756	0.407	< 0.0010 U	0.0082
2-CHLOROTOLUENE	mg/l	1.5	0.0034	< 0.0010 U	< 0.0010 U	0.0121
CHLOROBENZENE	mg/l	1.7	0.162	0.0300	0.0043	0.0435
m-Xylene & p-Xylene	mg/l	0.078	< 0.0020 U	< 0.0020 U	< 0.0020 U	< 0.0020 U
O-XYLENE	mg/l	0.078	< 0.0010 U	< 0.0010 U	< 0.0010 U	< 0.0010 U
TOLUENE	mg/l	1.7	0.0106	0.0018	< 0.0010 U	0.0021

Further support of the length of the PRP normal to groundwater flow is provided through groundwater profiling data collected during the supplemental remedial investigation (AECOM 2016). The GW-series locations were direct push pore water samples collected at specific depths shown. The WPT-series location employed the Waterloo profile tool to record a continuous profile of what is referred to as the index of conductivity, i.e., the relative conductivity, where lower values are to the left. WPT-4 and WPT-5 clearly show the high conductivity layer at 12 to 18 feet bgs.

4.2 BENCH-SCALE TREATABILITY STUDY

The Bench Study was completed using soil and groundwater samples collected from the Site during the Profile Study and treating the samples with AAKP oxidant to develop design parameters for application at the Site. The Bench Study consisted of three sub-studies;

1. Base buffering capacity
2. Total saturated zone oxidant demand
3. AAKP column study.

The baseline samples for the column study were collected on August 2, 2019 and the test was run over a 10-week period (October 3, 2019). This section discusses the study setup, results, and PRB design implications.

4.2.1 Base Buffering Capacity

Alkaline activated KP (AAKP) was selected for groundwater treatment at the Site because it is known to be an effective oxidizer for all the dissolved-phase COCs, including chlorobenzene, 1,2-dichlorobenzene, 2-clorotoluene, toluene, xylene and PCBs.

KP is most efficient when the groundwater pH is at or above 10.5. This is achieved by mixing the KP with an alkaline activator (thus AAKP), in this case lime. Therefore, this test was intended to quantify the amount of lime required to raise and maintain both Site soil and groundwater and groundwater only samples to pH 10.5 for up to seven (7) days.

Two base buffering capacity tests were completed, one designed to represent shallow conditions (to 15 feet bgs) and one designed to represent the treatment target conditions (to 35 feet bgs). The shallow zone test used groundwater collected from MW-100S (screened from 5 to 15 feet bgs) and soil collected from location BT-3 (10 to feet bgs) [see log **Appendix E**]. The deeper test used soil collected from location BT-4 (30 to 35 feet bgs) and groundwater collected from monitoring well

MW-1D (screened from 38 to 48 feet bgs). **Figure 2** depicts the location of these points. The sampling locations were selected because they were close to the proposed treatment area and the soil and groundwater was expected to be minimally impacted by the Site COCs.

The soil and groundwater samples for the base buffering capacity test were collected on July 18, 2019. Prior to collection of the groundwater samples, the monitoring wells were purged of three well volumes using a bailer. The samples were then collected using a bailer and placed into one-liter glass jars. The jars were placed in an ice-filled cooler and shipped to Peroxychem's treatability laboratory under chain of custody procedures.

A 25% sodium hydroxide solution was added to the saturated soils and allowed to equilibrate. The results indicate the following:

- 4.11 grams of 25% sodium hydroxide is required to raise the BT-3 soil pH to 10.5 and
- 4.11 grams of 25% sodium hydroxide is required to raise the BT-4 soil pH to 10.5.

For the groundwater tests, the 25% sodium hydroxide was slowly added, and the samples allowed to equilibrate. The results indicate:

- 0.48 grams of 25% sodium hydroxide is required to raise the MW-100S groundwater pH to 10.5 and
- 0.59 grams of 25% sodium hydroxide is required to raise the MW-1D groundwater pH to 10.5.

4.2.2 Total Oxidant Demand

Total saturated zone oxidant demand generally comes from three main reactive source components:

- Organic contaminant demand (target treatment compounds);

- Soil NOD;
- Groundwater (total dissolved and suspended solids) Oxidant Demand (GWOD)

The Total Oxidant Demand (TOD) is the combined demand associated with these reactive components. Soil NOD and GWOD result from the interaction of the oxidant with natural organics (organic acids such as humic and fulvic acids) and reduced metals (such as iron and manganese). As it is non-specific in its ability to react with organic and reduced species, activated KP will oxidize these non-target compounds, leading to an additional oxidant demand above and beyond the contaminant demand.

Relatively un-impacted soil and groundwater was collected from near the proposed treatment area of the Site and used to complete the NOD and GWOD studies. This test is best suited to determining the efficacy of the barrier concept as NOD and GWOD will represent a major sink for the oxidant (NOD, initially, and GWOD long-term).

4.2.2.1 Media Sample Collection

The soil samples for the soil NOD testing were collected on July 18, 2019 at location BT-3 from 10 to 15 feet below ground surface (bgs) (representative of shallow conditions) and at location BT-4 from 30 to 35 feet bgs (representative of deep conditions) (see **Figure 2** for locations). The soil samples were collected using a Geoprobe DPT drill rig with a Macrocore® soil sampler and disposable acetate liners. The soil samples were placed in one-gallon disposable plastic zipper bags, placed in an ice-filled cooler and shipped to Peroxychem's treatability laboratory under chain of custody procedures.

As with the base buffering capacity test, representative groundwater was collected from two monitoring wells, MW-1D and MW-100S. Monitoring well MW-100S is screened from 5 to 15 feet bgs and intended to represent the shallow groundwater zone. Monitoring well MW-1D is screened from 38 to 48 feet bgs and intended to represent the deep groundwater zone. These samples were collected using a bailer and placed into one-liter glass jars. The jars were placed in an ice-filled cooler and shipped to Peroxychem's treatability laboratory under chain of custody procedures.

4.2.2.2 Study results

The oxidant demand testing completed by Peroxychem indicated the soil at the Site contains a high NOD. Soil sample from BT-3 (10 to 15 feet bgs) was composed of black, coarse, sandy soil with minor inclusion of small sized gravel. After two days, the oxidant demand was 11.85 grams of KP per kilogram of dry soil and after seven days, the KP oxidant demand was 21.84 grams of KP per kilogram of dry soil. The soil collected from boring BT-4 (30 to 35 feet bgs) had lower NOD. The sample from BT-4 was wet, black and gray fine sand and it is representative of unimpacted conditions. After two days of testing, the KP demand was 4.67 grams per kilogram of dry soil. After seven days of testing, the KP demand was 13.62 grams of KP per kilogram of dry soil.

Assuming a treatment volume or 2,000 ft^3 and a soil density of 1.7 grams per cm^3, the mass of the soil in the treatment area is 96,277 kilograms (kg). Using the results from the BT-4 (30 to 35 feet bgs), because it is more representative of the treatment area, the KP NOD for the treatment volume will be 1,311.3 kg of KP. However, it is clear that only a small fraction of the soil volume will be exposed to KP, as the KP will be co-located with flowing groundwater. In addition, once the NOD is expended, the KP sink becomes de minimis.

The Site groundwater is not a significant source of TOD. The groundwater samples collected from monitoring well MW-100S and MW-1D indicated zero grams of KP were consumed after seven days of testing. Therefore, the applied AAKP will be available to destroy the target compounds.

4.2.3 AAKP Column Study

It is not the intent of the barrier to remediate Site source soil, but to treat impacted groundwater that has discharged from Site source soil (i.e., located down-gradient of the source area). However, within the barrier wall impacted soils will react with the AAKP (albeit in a diminishing capacity). Therefore, both impacted soil and groundwater were collected and utilized in the column tests. These tests are intended to represent worst-case scenarios of contaminant impact and leaching potential.

COC-impacted soil and groundwater sample locations were selected based on results of the Profile Study. Soil and groundwater sample analytical results are provided in **Table 6**.

4.2.3.1 Groundwater Sample Collection

Groundwater samples were collected from monitoring wells MP-3s and MP-3i on July 24, 2019 via low-flow sampling protocol for use in the treatability column studies. The treatability data are summarized in **Table 6**. The analytical data reports from the column study are provided in **Appendix C**.

Table 6

Summary of Bench Study Analytical Data

Ciba-Geigy RCRA Closure Project

			P0	P5				P10			P15				P20			P25			
Column A	**XMIP-3 Soil (µg/kg)[1]**	**MP-3i Composite Water (µg/L)**	**Feed (µg/L)**	**Feed (µg/L)**	**Treatment (µg/L)**	**Control (µg/L)**	**% Removal**	**Feed (µg/L)**	**Treatment (µg/L)**	**Control (µg/L)**	**Feed (µg/L)**	**Treatment (µg/L)**	**Control (µg/L)**	**% Removal**	**Feed (µg/L)**	**Treatment (µg/L)**	**Control (µg/L)**	**Feed (µg/L)**	**Treatment (µg/L)**	**Control (µg/L)**	**% Removal**
VOCs USEPA 8260																					
1,1-Dichloroethane	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1,2,4-Trichlorobenzene	**16,000**	50 U	**17 J**	20 U	40 U	**28**	-	-	-	-	50 U	**14.4 J**	**39 J**	63.08%	-	-	-	50 U	**14 J**	100 U	86.00%
1,2,4-Trimethylbenzene	-	-	**11 J**	20 U	40 U	**8.4 J**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1,2-Dichlorobenzene	**3,200,000**	**33,000**	**32,000**	**27,000**	**13,000**	**35,000**	62.86%	-	-	-	**20,000**	**10,800**	**39,000**	72.31%	-	-	-	**20,000**	**7,800**	**44,000**	82.27%
1,3-Dichlorobenzene	5,900 U	**41 J**	**44**	**36**	40 U	**11 J**	-	-	-	-	**33 J**	20 U	**50 U**	60.00%	-	-	-	**31 J**	20 U	100 U	80.00%
1,4-Dichlorobenzene	**28,000**	**360**	**370**	**290**	**84**	**200**	58.00%	-	-	-	**280**	**74**	**270**	72.59%	-	-	-	**220**	**52**	**230**	77.39%
2-Chlorotoluene	**16,000**	**6,200**	**6,100**	**4,900**	**32 J**	**160**	80.00%	-	-	-	**5,000**	**20**	**390**	94.87%	-	-	-	**3,600**	**13 J**	**800**	98.38%
4-Chlorotoluene	5,900 U	**200**	**210**	**170**	40 U	20 U	-	-	-	-	**160**	20 U	50 U	60.00%	-	-	-	**120**	20 U	100 U	80.00%
Benzene	1,500 U	**83**	**98**	**82**	20 U	**23**	13.04%	-	-	-	**82**	**4.2 J**	**44**	90.45%	-	-	-	**79**	**10 U**	**33 J**	69.70%
Chlorobenzene	**130,000**	**9,900**	**9,800**	**8,200**	**1,220**	**830**	-46.99%	-	-	-	**6,600**	**440**	**1,100**	60.00%	-	-	-	**7,600**	**138**	**630**	78.10%
cis-1,2 Dichlorethene	5,900 U	**100**	**100**	**83**	40 U	**69**	42.03%	-	-	-	**84**	20 U	**76**	73.68%	-	-	-	**83**	20 U	100 U	80.00%
Ethylbenzene	1,500 U	**39**	**45**	**31**	20 U	10 U	-	-	-	-	**23 J**	10 U	25 U	60.00%	-	-	-	**31**	10 U	50 U	80.00%
m&p-Xylenes	3,000 U	**63**	**79**	**62**	40 U	**32**	-	-	-	-	**59**	20 U	**48 J**	58.33%	-	-	-	**59**	20 U	**49 J**	59.18%
Methylene chloride	**11,000 J**	250 U	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Naphthalene	5,900 U	50 U	**13 J**	**11 J**	40 U	**26**	-	-	-	-	50 U	20 U	**32 J**	37.50%	-	-	-	**23 JB**	20 U	**50 JB**	60.00%
o-Xylene	1,500 U	**47**	**56**	**47**	20 U	**22**	9.09%	-	-	-	**47**	10 U	**32**	68.75%	-	-	-	**36**	10 U	**38 J**	73.68%
Tetrachlorethene	**520,000**	**190**	**200**	**180**	**3,000**	**5,900**	49.15%	-	-	-	**170**	**3,200**	**7,000**	54.29%	-	-	-	**160**	**2,200**	**5,100**	56.86%
Toluene	**3,000**	**100**	**110**	**89**	**13.6 J**	**25**	45.60%	-	-	-	**85**	**5.6 J**	**29**	80.69%	-	-	-	**83**	10 U	50 U	80.00%
trans-1,2 Dichloroethene	-	-	**7.1 J**	-	-	20 U	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trichloroethene	3,000 U	**25**	**30**	**24**	**14 J**	**48**	70.83%	-	-	-	**27**	10 U	**28**	64.29%	-	-	-	-	-	-	-
Vinyl chloride	-	-	**14 J**	**11 J**	40 U	20 U	-	-	-	-	**12 J**	20 U	50 U	60.00%	-	-	-	-	-	-	-
Total VOCs	**3,830,100**	**50,348**	**49,304**	**41,216**	**17,364**	**42,382**	59.03%	-	-	-	**32,662**	**14,558**	**48,088**	69.73%	-	-	-	**32,113**	**10,217**	**50,930**	79.94%
Acetone	-	-	-	200 U	**480**	200 U	-	-	-	-	500 U	**240**	500 U	-	-	-	-	500 U	**240**	1,000 U	-
PCBs USEPA 8082																					
Total PCBs	**980,000**	**4.4**	1.8 U	-	-	-	-	1.8 U	1.9 U	1.8 U	-	-	-	-	0.37 U	0.37 U	0.37 U	-	-	-	-
Inorganics																					
Sulfate (mg/L)	-	12	12.0	12	3,400	15	-		-	-	15	2,200	14	-	-	-	-	13 B	2,600	12 B	-
Persulfate (g/L)	-	-	-	-	45.55	-	-	-	44.51	-	-	44.66	-	-	-	44.45	-	-	44.33	-	-
Parameters																					
pH	-	6.72	6.7	6.74	11.4	6.79	-	6.68	12.29	6.67	6.72	12.52	6.66	-	6.65	12.35	6.75	6.7	12.56	6.76	-
ORP (mV)	-	-54.2	-39.9	307	375	293	-	327	291	320	414	284	372	-	315	291	311	73.3	260	261	-

Table 6

Summary of Bench Study Analytical Data

Ciba-Geigy RCRA Closure Project

			P0	P5				P10			P15				P20			P25			
Column B	XMIP-12 Soil (µg/kg)[1]	MP-3s Composite Water (µg/L)	Feed (µg/L)	Feed (µg/L)	Treatment (µg/L)	Control (µg/L)	% Removal	Feed (µg/L)	Treatment (µg/L)	Control (µg/L)	Feed (µg/L)	Treatment (µg/L)	Control (µg/L)	% Removal	Feed (µg/L)	Treatment (µg/L)	Control (µg/L)	Feed (µg/L)	Treatment (µg/L)	Control (µg/L)	% Removal
VOCs USEPA 8260																					
1,1-Dichloroethane	110 U	2.6	2.9	2.4	4.0 U	2.0	-	-	-	-	2.6	2.0 U	2.1	4.76%	-	-	-	2.5	2.0 U	2.0	0.00%
1,2,4-Trichlorobenzene	-	-	0.76 J	0.71 J	4.0 U	1.0 U	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1,2,4-Trimethylbenzene	-	-	-	1.0 U	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1,2-Dichlorobenzene	11,000	390	400	320	4.8	2.5	-92.00%	-	-	-	140	2.8	2.0	-	-	-	-	55	3.2	2.4	-33.33%
1,2-Dichloroethane	110 U	1.5	-	-	-	-		-	-	-	1.4	2.0 U	1.1		-	-	-	-	-	-	
1,3-Dichlorobenzene	110	1.0 U	-	1.0 U	4.0 U	0.81 J	-	-	-	-	-	-	-	-	-	-	-	1.0 U	2.0 U	0.45 J	-
1,4-Dichlorobenzene	2,400	6.5	5.9	5.0	4.0 U	4.5	11.11%	-	-	-	4.3	2.0 U	1.0 U	-	-	-	-	4.4	0.8 J	5.9 J	86.44%
2-Chlorotoluene	130	1.8	1.9 J	1.4	4.0 U	1.0 U	-	-	-	-	0.6 J	2.0 U	1.0 U	-	-	-	-	0.65 J	2.0 U	1.0 U	-
4-Chlorotoluene	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Benzene	240	11	11	4.1	2.0 U	0.91	-	-	-	-	-	-	-	-	-	-	-	9.1	0.48 J	0.5 U	4.00%
Bromomethane	-	-	-	3.0 U	32	3.0 U	-966.67%	-	-	-	3.0 U	3.8 J	3.0 U	-	-	-	-	-	-	-	-
Carbon Disulfide	-	-	-	2.0 U	8.0 U	0.73 J	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chlorobenzene	91,000	760	840	330	4.0 U	42	90.48%	-	-	-	0.98 J	12	0.42 J	-2757.14%	-	-	-	660	5.4	0.52 J	-938.46%
Chloroethane	-	-	-	1.0 U	3.6 J	1.0 U	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chloromethane	-	-	-	1.0 U	152	1.0 U	-	-	-	-	1.0 U	7.0	1.0 U	-	-	-	-	1.0 U	6.0	1.0 U	-
cis-1,2 Dichlorethene	110 U	110	110	93	4.0 U	50	92.00%	-	-	-	20	1.8 J	24	92.50%	-	-	-	98	1.8 J	9.6	81.25%
Ethylbenzene	36	5	4.7	2.5	2.0 U	0.5 U	-	-	-	-	-	-	-	-	-	-	-	2.8	1.0 U	0.5 U	-
m&p-Xylenes	45 J	0.92 J	1.7 J	0.41 J	4.0 U	0.8 J	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Methylene Chloride	560 U	1.8 J	-	-	-	-		-	-	-	-	-	-		-	-	-	-	-	-	
Naphthalene	800	1.0 U	-	1.0 U	4.0 U	1.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
o-Xylene	41	2.0	2.5	1.4	2.0 U	0.43 J	-	-	-	-	0.3 J	1.0 U	0.5 U	-	-	-	-	1.6	1.0 U	0.5 U	-
Tetrachlorethene	2,900	1.0 U	-	0.43 J	1.56 J	53	97.06%	-	-	-	0.5 J	2.0	20	90.00%	-	-	-	1.0 U	2.0 U	19	89.47%
Toluene	44	3.1	3.0	1.1	2.0 U	0.5 U	-	-	-	-	-	-	-	-	-	-	-	2.5	1.0 U	0.5 U	-
trans-1,2 Dichloroethene	110 U	5.0	4.8	3.8	4.0 U	2.3	-	-	-	-	4.1	2.0 U	1.7	-	-	-	-	4.7	2.0 U	1.6	-
Trichloroethene	25 J	6.7	6.3	5.3	2.0 U	2.6	23.08%	-	-	-	4.1	1.0 U	3.3 U	-	-	-	-	5.7	1.0 U	5.1	-
Vinyl chloride	110	44	49	36	4.0 U	14	71.43%	-	-	-	9.3	2.0 U	2.5	-	-	-	-	37	2.0 U	1.0 U	-
Total VOCs	105,840	1,352	1,444	808	194	178	-8.99%	-	-	-	188	30	57	47.37%	-	-	-	884	18	47	61.70%
2-Butanone	-	-	-	-	-	-	-	-	-	-	5.0 U	66	5.0 U	-	-	-	-	5.0 U	70	5.0 U	-
Acetone	-	-	-	7.1 J	800	18		-	-	-	10 U	340	10 U	-	-	-	-	6.8 J	400	10 U	-
PCBs USEPA 8082																					
Total PCBs	2,300	13	9.3	-	-	-	-	0.73 U	0.73 U	0.73 U	-	-	-	-	0.37 U	0.37 U	0.37 U	-	-	-	-
Inorganics																					
Sulfate (mg/L)	-	120	110	120	8,100	140	-	-	-	-	140	4,100	170 B	-	-	-	-	120 B	4,000	120 B	-
Persulfate (g/L)	-	-	-	-	40.88	-	-	-	39.89	-	-	24.87	-	-	-	42.26	-	-	42.89	-	-
Parameters																					
pH	-	6.38	6.32	6.32	2.01	6.59	-	6.27	2.07	6.26	6.31	12.18	6.39	-	6.39	9.35	6.46	6.28	12.21	6.58	-
ORP (mV)	-	-44.8	-37.7	-37.7	607	296	-	318	652	311	430	288	353	-	379	485	380	12.8	298	376	-

Notes:
VOCs = volatile organic compounds; PCBs = Polychlorinated biphenyl
µg/L - Micrograms per liter
g/L - Grams per liter
mg/L - milligrams per liter
µg/kg - micrograms per kilogram
U - Analyte not detected at Method Detection Limit (MDL)
J - Estimated Value between the MDL and reporting limit
B - Analyte identified in method blank

Thirty-five sample jars were collected from each well (total volume = 18.5 gallons) and were placed into ice-filled coolers and shipped under chain-of-custody procedures to the Peroxychem treatability laboratory. During purging, groundwater quality parameters including temperature, conductivity, dissolved oxygen (DO), oxidation-reduction potential (ORP) and turbidity were measured. Monitoring well MP-3s is screened from 5 to 13 feet bgs, and it is intended to represent shallow groundwater geochemistry, and monitoring well MP-3i is screened from 18 to 22 feet bgs, and it is intended to represent deeper groundwater geochemistry (see **Figure 2** for location). Sampling data from July 17, 2019 indicate that the groundwater at MP-3s contains 1.692 mg/L total VOCs (primarily 1,2-DCB and CB) and 0.0136 mg/L total PCBs. Groundwater at monitoring well MP-3i contains 60,315 mg/L total VOCs (primarily 1,2-DCB, 2-CT and CB) and less than 0.00009 mg/L total PCBs.

4.2.3.2 Soil Sample Collection

COC-impacted soil was selected for the treatability column studies based on results of the Profile Study. Soil samples from location XMIP-3, 15 to 18 feet bgs and XMIP-12, 9 to 14 feet bgs were collected using a direct push type drill rig and a Macrocore® soil sampler. These locations were selected to provide a worst-case scenario for treatment with AAKP. The soil samples were placed in one-gallon disposable zipper bags and sent to the Peroxychem treatability laboratory for use in the column studies.

4.2.3.3 Study Column Setup

The column treatability study was designed to evaluate the ability of AAKP to oxidize dissolved-phase COCs in groundwater at a constant seepage velocity (constant contact time). The study utilized soil and groundwater collected from the proposed treatment area, and it included both control (w/o AAKP applied) and treatment column runs (with AAKP applied).

Two treatment and control column sets were prepared to represent in-situ conditions at the Site. Columns A used homogenized highly impacted Site soil from location XMIP-3 (15 to 18 feet bgs) and Columns B used homogenized marginally impacted Site soil from location XMIP-12 (9 to 14 feet bgs). A sample of the soil from each location was collected for laboratory analysis for VOCs using USEPA Method 8260C and PCB Aroclors using USEPA Method 8082 to provide the initial conditions for the test (**Table 6**). The laboratory analytical data reports are provided in **Appendix C**.

In addition, the groundwater collected from each monitoring well (MP-3s and MP-3i) was separately homogenized to supply the test feed water indicative of each aquifer horizon. The homogenized water was submitted for laboratory analysis for VOCs using USEPA Method 8260C and for PCB Aroclors using USEPA Method 8082 to provide the initial conditions for the test (**Table 6**). The groundwater analyzed for PCBs was filtered using a 0.45 µm in-line filter.

Two test setups were constructed:

A. Column A and Control Column A: Highly impacted soil and groundwater prepared with XMIP-3 soil and flushed with MP-3i water.
B. Column B and Control Column B: Moderately impacted soil and groundwater prepared with XMIP-12 soil and flushed with MP-3s water.

Each 12-inch long and 4.8 cm inner diameter column (volume = 551.27 cubic centimeters [cm^3]) was loaded as follows:

- laboratory grade gravel;
- Site soil:
- KP, lime and sand mixture;
- Site soil and
- Laboratory grade gravel.

A summary of column packing in mass (grams) and layer thickness (inch) is provided in **Table 7**.

Table 7
Column Study Construction Details
Ciba-Geigy RCRA Closure Project

Column A	Gravel Bottom (g)	Bottom Layer of Site Soil (g/in)	KP (g)	Lime (g)	Sand (g)	AAKP Thickness (in)	Top Site Soil (g/in)
Control	28	93/1.0	0	0	571	7.7	233/2.5
AAKP	28	93/1.0	200	55	300	7.7	233/2.5

Column B	Gravel Bottom (g)	Bottom Layer of Site Soil (g/in)	KP (g)	Lime (g)	Sand (g)	AAKP Height (in)	Top Site Soil (g/in)
Control	28	75.8/1.0	0	0	570.8	7.7	196/2.5
AAKP	28	75.8/1.0	200	55	300	7.7	196/2.5

Given column dimensions and assuming an average total porosity of 30%, then the pore volume of each column is 165.38 cm^3. Feed groundwater was filtered through the column at 100 milliliters per day (mL/day). A pore volume was filtered through the column in 1.65 days (39.6 hours) and the contact time with AAKP was 1.06 days. At the feed rate of 100 mL/day, the groundwater seepage velocity through the column was 0.605 feet per day (ft/day).

4.2.3.4 Study Results – Column A

This test was run to provide a worst-case scenario to evaluate the ability of AAKP to destroy dissolved-phase contaminants given a fixed contact time and water seepage velocity. Results from the Column A testing are provided on **Table 6**.

As shown in **Table 6** the initial condition for soil total VOC content was 3,830,100 µg/kg (primarily 1,2-DCB) and the total PCB concentration in the soil was 980,000 µg /kg. The initial condition for feed water (P0) was 49,300 µg/L for total VOCs (primarily 1,2-DCB) and <1.8 µg/L for total PCB (note that dissolved-phase PCBs are shown to be present at some level given the initial composite sample value of 4.4 µg/L).

Shown on **Table 6** are result data at as a function of pore volumes (PV) flushed: time = 0 (P0), and at 5-pore volume (PV) increments (P5, P10, P15, P20, P25).

Control Column A: Data from the control column across all time indicate no significant change in concentration given equilibrium partitioning considerations. At P20, the PCB detection limit was lowered to below the target level of 0.5 µg/L, and PCBs were not detected in either the feed water or effluent water of the control column. This data implies that PCBs are highly adsorbed and immobile under equilibrium conditions. The pH remained essentially constant (6.7) over the experiment.

Treatment Column A: The AAKP was able to raise the pH to above the 10.5 target for the entire experiment. This indicates is aquifer-buffering capacity is not a significant deterrent to KP activation using 22% lime by weight.

AAKP treatment is shown to be effective for all the detected contaminants, and after 25 PVs (41.25 days) only 1,2-DCB remains above its MPS (7,800 µg/L measured versus MPS = 94 µg/L) and the reduction in concentration of the five MPS compounds is: 1,2-DCB = 82%, CB = 78%, 2CT = 98%, total XYL = 100% (ND [<20 µg/L]); TOL = 100% (ND [<50 µg/L]) as compared to the results of the control column.

4.2.3.5 Study Results – Column B

This test was run to provide a more likely treatment scenario for the proposed purpose of the barrier. Results from the Column B testing are provided on **Table 6**. CB and 1,2-DCB represent the highest concentration MPS compounds, with only 1,2-DCB in excess of its MPS. The data are similar to that collected for Column A in terms of pH adjustment (above the 10.5 target) and COC destruction efficiency. At PV 15, all MPS compounds are below their respective MPS target.

4.2.4 Bench Scale Study Conclusions

The following general conclusions relative to AAKP effectiveness and PRB design are made based on the bench data presented above.

1. Base buffering capacity: The soil and groundwater do not have a significant buffering capacity and using lime to raise the pH to > 10.5 is effective given the geochemistry of the target treatment interval.
2. NOD and GWOD is will not preclude use of the technology.
3. AAKP Column Study
    a. The AAKP mixture was able to rapidly increase the pH to the target 10.5 after 5 PVs flushed, maintained the required pH for 25 pore volumes (41.25 days), and did not show indications of depletion.
    b. PCBs were found to be either not mobile as a dissolved phase, or completely treated by the AAKP prior to discharge after five pore volumes.
    c. Within five pore volumes, the concentration of sulfate and persulfate significantly increased indicating rapid dissolution and reaction of the persulfate in the column.
    d. After of 25 pore volumes, at a flow rate of 0.605 feet/day, equivalent to approximately 41.25 days of field treatment, AAKP reduced the concentration of the total VOCs and MPS compounds 80% or more as compared to the control, with only 1,2-DCB remaining in excess of its MPS.
    e. The KP remained in the column at uniform levels for the exchange of 25 PVs and did not show indications of depletion.
    f. These results indicate that treatment of the MPS compounds in the aquifer feasible using AAKP, and it is able to effectively address the dissolved phase COCs given contact time of 41.25 days. It also shows that for seepage velocities of approximately 0.605 feet/day or less, the barrier can be feasibly maintained.

4.3 FIELD-SCALE TREATABILITY STUDY

The purpose of the Field Study was to evaluate the ability of AAKP to treat VOCs dissolved in groundwater at the Site, as well as to evaluate the effectiveness of activated AAKP to oxidize dissolved PCBs in groundwater at the Site. The study design included the following:

1. Select an existing representative well for testing, MP-3i. This well is a 1.5-inch diameter well screened from 18 to 22 feet bgs and it is impacted with site-related compounds (see **Table 6**).
2. Conduct slug testing to estimate aquifer hydraulic conductivity.
3. Conduct baseline groundwater sampling prior to the deployment of the AAKP socks (**Table 8**). These samples were collected using the USEPA low-flow method and analyzed for VOCs using USEPA Method 8260C and PCB Aroclors using USEPA Method 8082. For PCB analysis, CEC collected an unfiltered and a split filtered sample. Field parameters including DO, pH, ORP, conductivity, temperature and turbidity we collected during purging of the well. The samples were collected in the appropriate, preserved laboratory provided glassware and submitted to ESS Laboratories on-ice and under Chain of Custody procedures. The purge data from the July 17, 2019 sampling event are provided in **Appendix C**.
4. Deploy AAKP socks in the well, using the same methods intended for the PRB installation. CEC prepared socks containing a blended mixture of AAKP and lime with a volumetric ratio of 1.8:1 (AAKP:lime)[5]. Four socks were deployed on July 30, 2019, with each sock having the following dimensions: 1.25-inch diameter, 2.5 feet long; AAKP volume = 0.021 ft^3.
5. Periodic effectiveness sampling. Between July 31, 2019 and August 14, 2019, field parameters and groundwater analytical samples were collected while the socks were in place using a peristaltic pump and dedicated polyethylene tubing positioned between the lower two socks and in line with the screen. Dissolved KP was analyzed using field KP

[5] This ratio predated the results of the bench study and was recommended by Peroxychem based on their experience with AAKP.

test kits provided by Peroxychem and pH was monitored using a calibrated water quality meter. Groundwater samples were collected on August 14, 2019 for laboratory analysis of VOCs and PCB Aroclors. The groundwater sample collected for PCB Aroclors was field filtered using a 0.45 µm in-line filter to remove suspended particulates. The groundwater sampling results are summarized in **Table 8.** The analytical data reports are provided in **Appendix C.**

Table 8
Field Study Analytical Data Summary
Ciba-Geigy RCRA Closure Project

	MP-3i Water						
Sample Name	**Untreated Filtered**		**Treated Filtered**		**% Removal**	**USEPA Drinking Water MCL**	**Media Protection Standards (MPS)**
Sample Date	**07/17/2019**		**08/14/2019**				
Depth to Groundwater (feet):	**6.53**		**7.22**				
Laboratory Sample ID:	**19G0539-02**		**19H0465-02**				
PCBs (ug/L)							
Aroclor 1016	0.09	U	0.25	U	-	0.5	-
Aroclor 1221	0.09	U	0.25	U	-	0.5	-
Aroclor 1232	0.09	U	0.25	U	-	0.5	-
Aroclor 1242	0.09	U	0.25	U	-	0.5	-
Aroclor 1248	0.09	U	0.25	U	-	0.5	-
Aroclor 1254	0.09	U	0.25	U	-	0.5	-
Aroclor 1260	0.09	U	0.25	U	-	0.5	-
Aroclor 1262	0.09	U	0.25	U	-	0.5	-
Aroclor 1268	0.09	U	0.25	U	-	0.5	-
Total PCBs	0.09	U	0.25	U	-	0.5	-
VOCs (ug/L)							
1,2-Dichlorobenzene	**40,900**		**8,930**		78.17%	-	94
2-Chlorotoluene	**4,990**		367		92.65%	-	1,500
Chlorobenzene	**13,600**		**1,930**		85.81%	-	1,700
Toluene	127		100	U	-	-	1,700
Xylene O	76.2		**100**	**U**	-	-	78
Xylene P,M	**104**		**200**	**U**	-	-	78
*Total Xylene	**180.2**		**300**	**U**	-	-	78
pH (Standard Units)							
pH	6.25		12.40		-	-	-

Notes:

VOCs = Volatile organic compounds; PCBs = Polychlorinated Biphenyl

ug/L = Micrograms per liter; -- = No standard; NT = Not Tested; NE = Not Established; - = Not calculated due to elevated Detection Limits (DL) and/or compounds not detected above DL

U = Analytes below laboratory method detection limits

* Sum of O, P&M Xylene.

Bold values are greater than either the MPS or MCL

4.3.1 Slug Test

As discussed in **Section 3.1**, an important design parameter is the groundwater seepage velocity, which affects contaminant contact time and AAKP dissolution rate. CEC conducted a rising head slug test at monitoring well MP-3s and a rising and falling head slug test at monitoring well MP-3i on July 23, 2019. A transducer was deployed to approximately one-foot from the base of each well and the groundwater was allowed to stabilize. A slug of known volume was lowered into the well and was suspended between the well screen intervals. The change in groundwater elevation was then automatically logged every 5 seconds. This data was then analyzed using AQTESOLV software to calculate the hydraulic conductivity using the Bouwer-Rice Method for each well **(Appendix D**). The hydraulic conductivity estimates are provided in **Table 9**.

Table 9
Field –Scale Treatability Test Slug Test Summary
Ciba-Geigy RCRA Closure Project

Monitoring Well	Slug Test Type	Conductivity (cm/sec) [ft/d]
MP-3s	Rising Head	3.57×10^{-3} [10]
MP-3i	Falling Head	4.53×10^{-4} [1.3]
MP-3i	Rising Head	7.72×10^{-4} [2.2]

cm/sec = centimeters per second
ft/d = feet per day

These values are significantly lower than the screening levels provided from the MiHpt tool; however, these values are consistent with those derived during the 1995 RCRA Facility Investigation (RFI) slug testing.

The Supplemental Remedial Investigation (AECOM 2016a) indicates a hydraulic gradient on the order of 0.02 foot/foot. Current hydraulic gradient data is in agreement with data collected from the Supplemental Remedial Investigation. The hydraulic gradient in the study area was 0.03 foot/foot on November 25, 2019, 0.02 foot/foot on February 13, 2020 and 0.02 foot/foot on February 19, 2020. With a hydraulic gradient of 0.02 foot/foot and assuming an effective porosity of 30%, given the established hydraulic conductivity, the seepage velocity is expected to be less than or equal to 0.7 feet/day.

4.3.2 Study Result

As shown in **Table 10**, the sock deployment resulted in an elevated pH of greater than 10.5 and elevated KP concentrations (both parameters similar to in magnitude to those measured during the bench test). It was estimated by observation that approximately 40% of the AAKP in the sock was dissolved by the end of the test (note that the volume of AAKP deployed was 0.084 ft^3, which is a small fraction of that to be used in each dedicated PRB wells).

Table 10
Field –Scale Treatability Test Field Screening Data for MP-3i
Ciba-Geigy RCRA Closure Project

Date:	pH	Temperature (°C)	Depth to water (feet)	Field Estimated % Dissolved	Persulfate (g/L)	Sock Weight (kg)
7/17/2019	6.25	17.31	NM	NA	NA	NA
7/25/2019	NM	16.84	5.44	NA	NA	NA
7/31/2019	12.2	NM	NM	10%	0	NM
8/2/2019	12.4	NM	NM	30%	NT	NM
8/5/2019	12.1	NM	NM	30%	21.5	NM
8/7/2019	12.6	17.6	NM	30%	26.3	NM
8/9/2019	12.5	18.1	6.96	30%	26.3	NM
8/12/2019	12.3	19.5	7.17	30%	23.2	NM
8/14/2019	12.4	16.1	7.22	30-40%	20.0	NM

NA = Not applicable
NM = Not Measured
kg = Kilograms
g/L = grams per Liter

PCBs were not detected in the groundwater samples collected from monitoring well MP-3i.

As indicated in **Table 8**, the total VOC concentration in the initial groundwater sample collected from monitoring well MP-3i was 60,302 µg/L and the constituents were dominated by 1,2-DCB (40,900 µg/L) and CB (13,600 µg/L). By day 29, the total VOCs had been reduced to 11,229 µg/L. The groundwater concentration of 1,2-DCB decreased 78.2% to 8,930 µg/L and the CB decreased 85.8% to 1,930 µg/L. These data were collected with the socks remaining in the well and the well was not purged prior to sampling.

4.3.3 Conclusions

Based on the data collected, the following observations are made:

1. Seepage velocity – Based on slug-test data and historical data, the hydraulic conductivity associated with the target saturated zone is less than or equal to 10 feet/day. Assuming an effective porosity of 30%, given the established hydraulic conductivity and gradient, the expected seepage velocity is expected to be less than or equal to 0.7 feet/day.
2. The data collected at MP-3i closely aligns with that collected during the bench study.
3. AAKP reactions are not exothermic, and they do not significantly affect groundwater temperature.

4.4 CONCLUTIONS RELATIVE TO PRB DESIGN

The purpose for the PRB is to provide a reactive zone in the aquifer through which groundwater, impacted by Site-related compounds in excess of one or more MPS criteria, passes and is treated by chemical oxidation to meet MPS criteria before it discharges into the Patuxent River hydrologic system. Therefore, the key PRB design parameters include:

1. PRB dimensions (depth and length normal to groundwater flow and width parallel to groundwater flow), and
2. Oxidant properties as they are affected in the hydrogeologic environment and as they are capable of degrading the target compounds.

The data discussed above provides the following conclusions relative to PRB design.

<u>PRB area normal to groundwater flow:</u> The major ongoing source that is impacting groundwater is shown to be the result of leaching from a historical release from the former building 16 sump, which failed and discharged solvent laden process water including VOCs and PCBs. This impact is isolated stratigraphically in a coarse-grain layer deposit that is apparent from approximately 14 to 17 feet bgs (the coarse-grain layer is bound below by fine grain material), with DNAPL shown to penetrate to a depth of 20 feet bgs.

Given this characterization and the characterization of groundwater flow from the upland to the river discharge point in the presence of the river bulkhead, consider the following PRB cross section:

- PRB depth is 22 to 32 feet bgs to both avoid source material and intercept dissolved phase MPS compound mass moving under the sheet pile bulkhead.
- PRB length normal to groundwater flow: The length of impact is approximated by the 1,2-DCB plume shown in **Figure 7**. This plume is centered around the characterized impact associated with the jet sump, and there appears to be a preferential flow path connecting the upland and river hydrologic regimes. This length is approximately 40 feet.

<u>PRB thickness parallel to groundwater flow:</u> The PRB must be wide enough to provide a sufficient reactive zone contact time to destroy the target compounds. This parameter is thus a function of the following:

1.) Oxidant contaminant composition and magnitude, where mixtures and concentration magnitude affect the required residence time.
2.) Groundwater seepage velocity.

Given a groundwater seepage velocity of less than 1 foot/d and Column A bench results (high mass), a contact time on the order of 10 days should be sufficient to achieve the objectives. This contact time equates to a barrier thickness of 10 feet.

5.0 PRB AND MONITORING NETWORK INSTALLATION

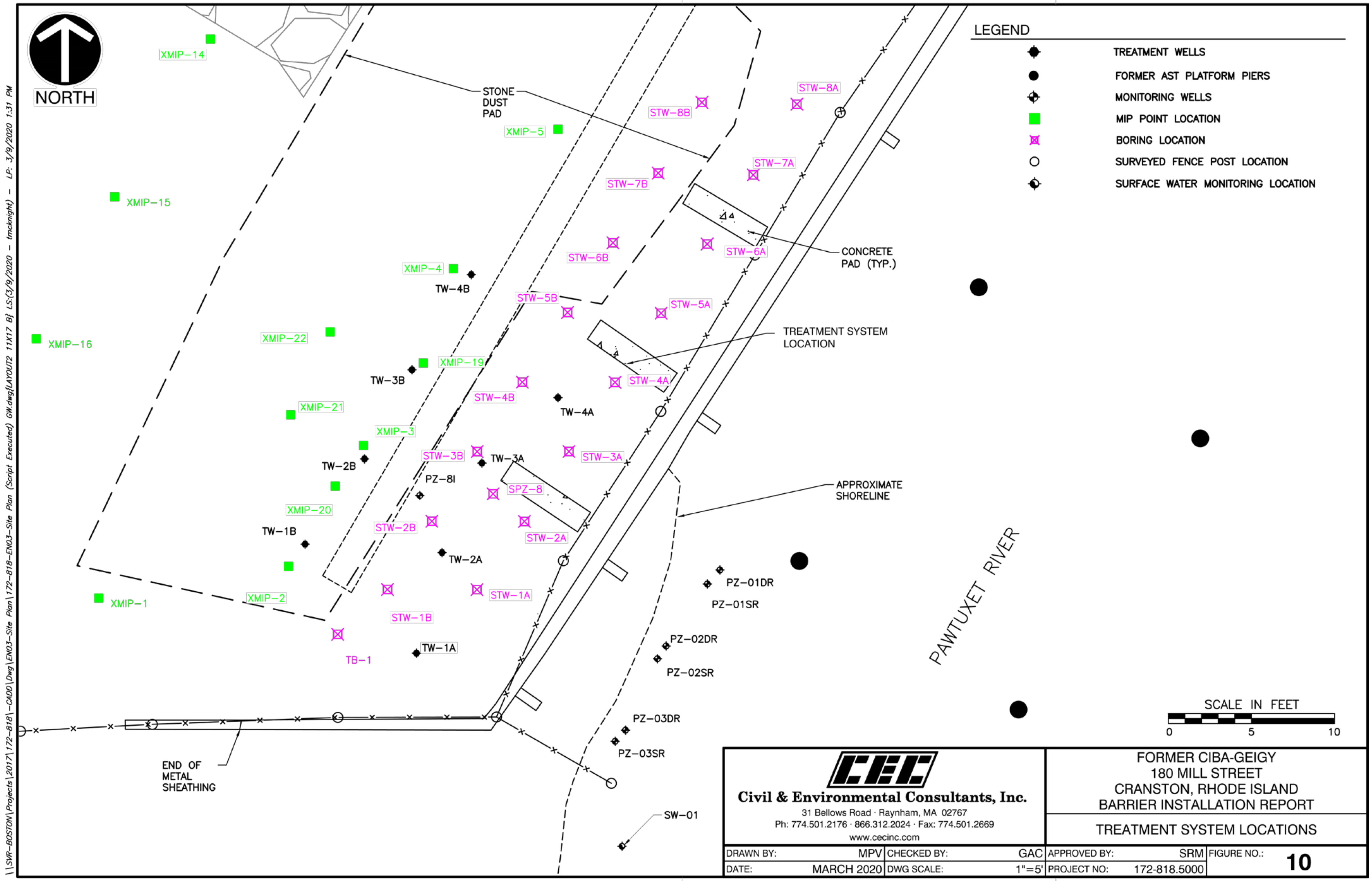
5.1 PRB INSTALLATION

The target plan-view PRB area consistent with the findings from **Section 4** is shown on **Figure 10**, where eight treatment wells (TW-series) were installed adjacent to soil boring locations STW-1A/B through STW-4A/B and a performance monitoring well, PZ-8i, was installed between TW-2A and 2B.

The first treatment wells installed were TW-1A and TW-4A, outside the DNAPL zone. These locations were first cored via DPT rig to verify the lithology and target screened interval for the PRB. Boring logs and well construction details are provided in **Appendix E**. The logs show that the treatment wells are screened a fine silty sand layer below the coarse sand layer.

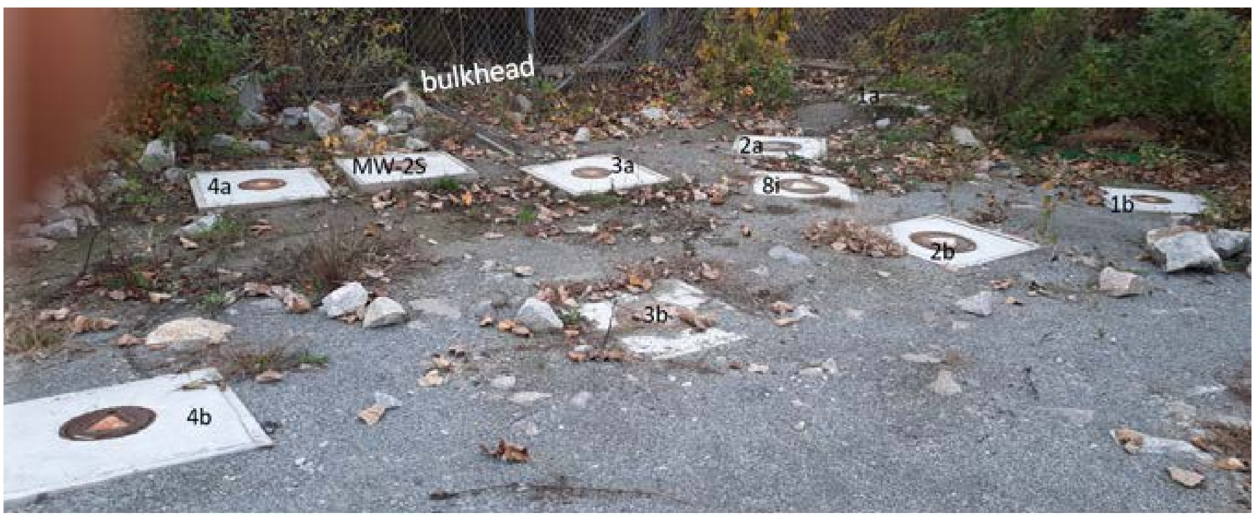
Treatment wells in the DNAPL area (TW-2A, TW-2B and TW-3B) and the performance monitoring well PZ-8i were constructed with a double casing to prevent vertical migration of DNAPL from the coarse sand layer. In these cases, an 8-inch diameter steel outer casing was grouted into the silty layer to 20 feet bgs and allowed to set before completing the well installation.

Given proximity of the barrier to up-gradient source material and down-gradient bulkhead, the remaining treatment wells were installed (September 23, 2019 to September 30, 2019) in two parallel transects oriented normal to groundwater flow and spaced approximately 5 feet apart: Transect A (approximately 5 to 10 feet from the bulkhead) and B (approximately 15 feet from the bulkhead). The treatment wells were installed using a hollow stem auger drill rig. Each treatment well was installed in a 10.25-inch boring to 32 feet bgs and constructed of a 4-inch diameter polyvinyl chloride (PVC) riser and ten feet of 0.010-inch slotted PVC screen encased in a 10.25-inch diameter #001 sand pack. Each well is screened from 22 to 32 feet bgs and is completed at the surface with a curb box and concrete pad.


NORTH
LEGEND
TREATMENT WELLS
FORMER AST PLATFORM PIERS
MONITORING WELLS
MIP POINT LOCATION
BORING LOCATION
SURVEYED FENCE POST LOCATION
SURFACE WATER MONITORING LOCATION
STONE DUST PAD
CONCRETE PAD (TYP.)
TREATMENT SYSTEM LOCATION
APPROXIMATE SHORELINE
END OF METAL SHEATHING
PAWTUXET RIVER
XMIP-14
XMIP-5
XMIP-15
XMIP-4
XMIP-16
XMIP-22
XMIP-19
XMIP-21
XMIP-3
XMIP-20
XMIP-2
XMIP-1
STW-8A
STW-8B
STW-7A
STW-7B
STW-6A
STW-6B
STW-5A
STW-5B
STW-4A
STW-4B
STW-3A
STW-3B
SPZ-8
STW-2A
STW-2B
STW-1A
STW-1B
TB-1
TW-4B
TW-3B
TW-4A
TW-3A
TW-2B
PZ-8I
TW-1B
TW-2A
TW-1A
PZ-01DR
PZ-01SR
PZ-02DR
PZ-02SR
PZ-03DR
PZ-03SR
SW-01
SCALE IN FEET
0
5
10
Civil & Environmental Consultants, Inc.
31 Bellows Road · Raynham, MA 02767
Ph: 774.501.2176 · 866.312.2024 · Fax: 774.501.2669
www.cecinc.com
FORMER CIBA-GEIGY
180 MILL STREET
CRANSTON, RHODE ISLAND
BARRIER INSTALLATION REPORT
TREATMENT SYSTEM LOCATIONS
DRAWN BY: MPV
CHECKED BY: GAC
APPROVED BY: SRM
FIGURE NO.: 10
DATE: MARCH 2020
DWG SCALE: 1"=5'
PROJECT NO: 172-818.5000

In addition to the treatment wells, one two-inch diameter piezometer (PZ-8i) was installed between the transects and down-gradient of treatment well TW-2B to provide a monitoring point to evaluate the effectiveness of the remedy. Piezometer PZ-8i is constructed with 10 feet of 0.010-inch slotted PVC well screen set from 22 to 32 feet bgs. The well has PVC riser and is finished at the surface with a curb box and concrete pad. **Appendix E** contains the well construction log for PZ-8i. **Figure 11** provides a photo of the field area.

Figure 11
Photograph of the AAKP Treatment Area
Ciba-Geigy RCRA Closure Project



5.2 RIVER PIEZOMETER INSTALLATION

In 2011, five drive-point piezometers were installed in the river as part of the SSRI (AECOM 2016a) to monitor upwelling groundwater quality (shallow/deep pairs). During the river piezometer baseline-sampling event on October 2, 2019, the piezometers were found to be compromised and groundwater samples were not collected. Therefore, on October 15, 2019, six new drive-point piezometers (3 shallow/deep pairs) were installed in the river to provide data regarding the groundwater quality below the river and within the expected zone of influence of the PRB. The construction details of the river piezometers are summarized in **Table 11** below.

Table 11
River Piezometer Construction Details
Ciba-Geigy RCRA Closure Project

Piezometer	Depth (feet bss)	Screened Interval (feet bss)
PZ-1SR	9	7 – 9
PZ-1DR	14	12 – 14
PZ-2SR	9	7 – 9
PZ-2DR	13	11 – 13
PZ-3SR	9	7 – 9
PZ-3DR	12	10 -12

bss – Below sediment surface
SR = shallow river
DR = deep river

The deep piezometers are intended to monitor contaminant mass attenuation along the primary groundwater mass transport pathway as it emerges from under the sheet-pile bulkhead, followed by the shallow piezometers. While the target depth of the deep locations was 15 to 17 feet below sediment surface (bss), the actual depths are less due to refusal using the installation technique (slide hammer). An assessment of the adequacy of the performance-monitoring network is part of the PRB monitoring program (discussed in **Section 6**).

5.3 AAKP TREATMENT

On September 30, 2019, AAKP mixture of 22% lime and 78% KP by volume (recipe derived from the bench work) was blended and placed into porous socks for deployment in the PRB wells, where the socks span almost the entire water column (approximately 20 feet of water in each well) to allow for additional AAKP to enter the groundwater system. PRB sock preparation, deployment and degradation monitoring SOPs are provided in **Appendix F**. **Figure 12** provides an illustration of a typical PRB well.

Figure 12
Typical PRB Well
Ciba-Geigy RCRA Closure Project

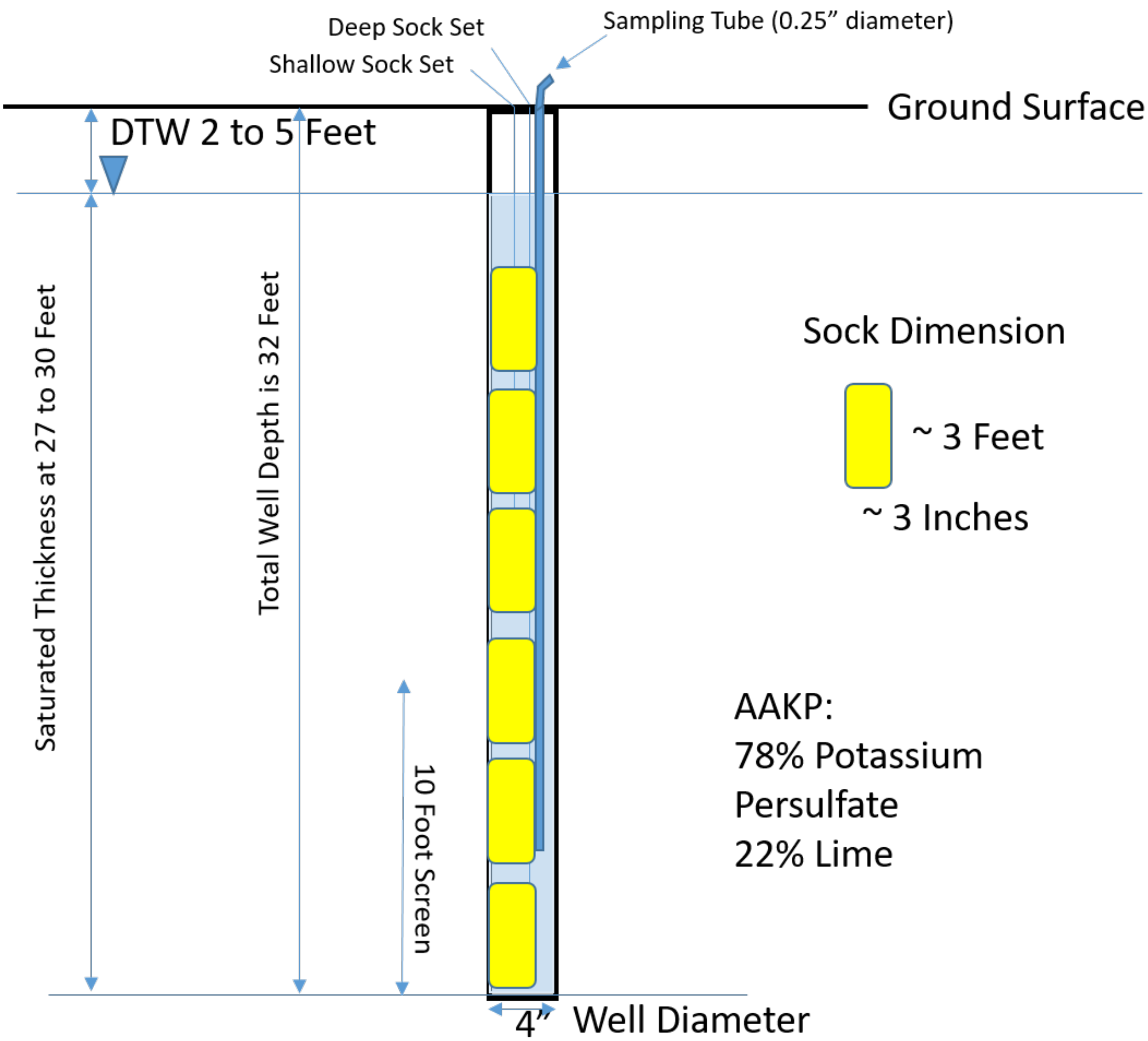


Illustration of a treatment well showing screened interval and depth and sock configuration. The socks are deployed on two separate strings (shallow and deep). A dedicated water sample tube is positioned at the center of the well screen.

By September 30, 2019, AAKP was installed in seven of the eight treatment wells. The socks are deployed on two separate strings (upper and lower) in the treatment wells. The socks are allowed to saturate overnight and then the weight of each string within the groundwater column is measured to provide an initial condition upon which to assess AAKP depletion over time.

Treatment socks were not initially placed in treatment well TW-2B because of observed DNAPL in the well. Recall that this well is directly down-gradient of the DNAPL detected at XMIP-3, and that before installation an outer casing was installed to 20 feet bgs. Approximately 16 to 32 ounces of DNAPL was removed from the well over several weeks using a combination of extraction using a peristaltic pump followed by the use of an oil absorptive sock. Once the DNAPL was cleared (the source of which was likely due to medium disturbance during installation), AAKP was applied to the well on November 25, 2019.

5.3.1 Baseline Monitoring

Prior deployment of the AAKP to the treatment wells, a baseline groundwater-monitoring event was complete on September 28, 2019 and the samples were analyzed as summarized in **Table 12**.

Table 12
Treatment Well Baseline Groundwater Sampling
Ciba-Geigy RCRA Closure Project

Location	VOCs[1]	PCBs[2]	Sulfate[3]	Persulfate[4]
TW-1A	X	X	X	X
TW-1B	X	X	X	X
TW-2A	X	X	X	X
TW-2B	-	-	-	-
TW-3A	X	X	X	X
TW-3B	X	X	X	X
TW-4A	X	X	X	X
TW-4B	X	X	X	X
PZ-8i	X	X	X	X

Table 12
Treatment Well Baseline Groundwater Sampling
Ciba-Geigy RCRA Closure Project

Location	VOCs[1]	PCBs[2]	Sulfate[3]	Persulfate[4]

Analyses:

1. VOCs analyzed using USEPA Method 8260C.
2. PCB Aroclors analyzed using USEPA Method 8082 (Filtered)
3. Sulfate analyzed using USEPA Method 9056
4. Persulfate measured using a PeroxyChem field test kit

Note:

TW-2B was not sampled during this event due to the presence of DNAPL in the well.

Samples collected from the treatment wells and the piezometer were collected following the USEPA Low-Flow protocol using a submersible pump with the pump set approximately two feet above the bottom of each well. Groundwater quality parameters including DO, ORP, conductivity, temperature, turbidity and pH were monitored during purging of the treatment wells. Groundwater samples for PCB analysis were filtered using 0.45-micron (µm) disposable in-line filters.

The six river piezometers were installed on October 15, 2019. The new piezometers were to replace the existing five piezometers and provide groundwater quality data from below the riverbed. The piezometers were developed to remove fines from the formation and each piezometer was sampled on October 16, 2019. Groundwater samples were collected using USEPA low flow sampling techniques with the tubing inlet set at the center of each piezometer screen. Groundwater quality parameters including DO, ORP, conductivity, temperature, turbidity and pH were monitored during purging of the piezometers. Groundwater samples for PCB analysis were filtered using 0.45-micron (µm) disposable in-line filters. **Table 13** summarizes the baseline sampling of the river piezometers.

Table 13
River Piezometer Baseline Groundwater Sampling
Ciba-Geigy RCRA Closure Project

Location	VOCs[1]	PCBs[2]	Sulfate[3]	Persulfate[4]
PZ-01DR	X	X	X	X
PZ-01SR	X	X	X	X
PZ-02DR	X	X	X	X
PZ-02SR	X	X	X	X
PZ-03DR	X	X	X	X
PZ-03SR	X	X	X	X

Analyses:

1. VOCs analyzed using USEPA Method 8260C.
2. PCB Aroclors analyzed using USEPA Method 8082 (Filtered)
3. Sulfate analyzed using USEPA Method 9056
4. Persulfate measured using a PeroxyChem field test kit

In addition to the groundwater monitoring, two surface water-monitoring points were established to monitoring the surface water quality for indications of impact from the remedial additives. Location SW-01 is just upstream from the river piezometers and is used to evaluate the river quality upstream of the Site. Location SW-02 is a surveyed stilling well attached to the platform for the MW-31 series monitoring wells. This location is used to monitor surface water quality immediately downstream of the treatment area. The location of the monitoring points are depicted in **Figure 10**.

The baseline data for the upland treatment wells and PZ-8i are summarized in **Table 14**.

Table 14
Treatment Well Baseline Groundwater Sampling Data
Ciba-Geigy RCRA Closure Project

	TW-1A	**TW-2A**	**TW-3A**	**TW-4A**	**TW-1B**	**TW-2B**	**TW-3B**	**TW-4B**	**PZ-8i**
1,2-DCB	3.5	**1,260**	42.8	5.0	65.3	NS	**3,280**	35.9	**2,290**
CB	49.9	274	572	6.7	92.3	NS	796	35.7	314
2-CT	< 1.0	2.1	<1.0	<1.0	<1.0	NS	5.7	<1.0	6.8
Tol	<1.0	5.7	73.6	<1.0	1.5	NS	37.7	<1.0	13.5
Xyl	<3.0	<3.3	11.4	<3.0	<3.0	NS	7.4	<3.0	3.6
PCBs	<0.09	<0.09	<0.09	<0.09	<0.09	NS	<0.10	<0.09	**2.72**
pH	6.80	10.06	7.88	6.95	7.44	NS	7.42	6.64	6.76
Sulfate	16.8	34.0	18.8	8.7	7.9	NS	24.0	6.6	22.0
DO	0.14	0.36	0.08	0.19	0.13	NS	0.90	0.24	0.14
ORP	-14.8	-239.5	-151.5	-87.5	-104.9	NS	-147.6	-109.6	-97.6

1,2-DCB = 1,2-Dichlorobenzene
CB = Chlorobenzene
2-CT = 2 Chlorotoluene
Tol = Toluene
Xyl = Total Xylenes
All COC data is reported in µg/L
DO = Dissolved Oxygen
DO and sulfate data is reported mg/L
ORP = Oxidation Reduction Potential and is reported in millivolts (mV)
Bold values = greater than respective MPS or MCL
NS = Not Sampled

Data from the baseline sampling shows the following:

1) While wells TW-2b and PZ-8i were cased to 20’ bgs to prevent the potential for NAPL to infiltrate into the conduit, both wells showed signs of NAPL accumulation. This occurrence is being remedied by the installation of SoakEase, an absorbent purposed of this application (see SOP in **Appendix F**).
2) For the upland wells, dissolved-phase 1,2-DCB dominates on a mass basis with the highest levels occurring at TW-2A, TW-3B and PZ-8i. The only well with detected PCBs was PZ-8i. The distribution and composition of impacts is consistent with transport from the XMIP-03 source area.

3) The pH ranged from 6.64 in groundwater from Treatment Well TW-4B to 10.06 in groundwater from treatment well TW-2A. DO and ORP data indicate the groundwater in the treatment area has minimal DO and the environment is strongly reducing.
4) The initial sulfate concentration in the groundwater ranged from 6.60 mg/L at TW-4B to 34 mg/L at TW-2A.

The baseline data for the river piezometers are summarized in **Table 15** below.

Table 15
River Piezometer Baseline Groundwater Sampling Data
Ciba-Geigy RCRA Closure Project

	PZ-01SR	PZ-02SR	PZ-03SR	PZ-01DR	PZ-02DR	PZ-03DR
1,2-DCB	**336**	**98**	**656**	**4,480**	<1.0	28.2
CB	**9,070**	**4,680**	**2,380**	233	26.3	559
2-CT	60.5	34.2	7.7	6.4	<1.0	9.2
Tol	37.5	8.6	1.2	3.5	<1.0	1.5
Xyl	45.7	14.3	<3.4	9.5	<2.0	4.6
PCBs	**1.84**	**1.81**	**1.0**	<0.1	0.16	0.41
pH	6.85	7.14	6.83	6.99	6.85	7.14
Sulfate	36.5	37.5	<5.0	<5.0	26.4	13.0
DO	0.40	0.33	0.39	0.31	1.22	0.37
ORP	183.4	145.9	154.7	135.3	195.8	161.9

1,2-DCB = 1,2-Dichlorobenzene
CB = Chlorobenzene
2-CT = 2 Chlorotoluene
Tol = Toluene
Xyl = Total Xylenes
All COC data is reported in µg/L
DO = Dissolved Oxygen
DO and sulfate is reported mg/L
ORP = Oxidation Reduction Potential and is reported in millivolts (mV)
Bold values = greater than respect MPS or MCL

The following observations are made based on these data relative to transport from the upland source area:

1) For the deep piezometers.
   a) The results are consistent with the recent upland characterization data reported here, where 1,2-DCB dominates the concentration in groundwater.
   b) While PCBs are present in upland soils, they are not are not mobile in groundwater.
   c) The results are consistent with groundwater flow (see AECOM [2016a] and Section 5.3.3 below).
   d) The MPS compound detections are similar to those detected during the SSRI (Figures 6, 7, and 8).
   e) The highest detection is in the most downgradient sample point, PZ-01DR. This observation is consistent with the CSM for impacted groundwater upwelling in the downstream direction. This observation also indicates that at least one additional downgradient location is necessary to confirm the sufficiency of the PRB's lateral extent (discussed further in **Section 6**).
2) For the shallow piezometers
   a) The concentration gradient is reversed from what would be expected if the source of the shallow pore water impact was transport from below the bulkhead, where higher concentrations are generally detected for all MPS compounds except 1,2-DCB in the shallower horizon.
   b) The shallow zone composition is dominated by CB, and PCBs are also detected above the MCL.
   c) The observed distribution (CB the dominant MPS compound with PCB present) is consistent with documented discharges directly to sediment from past waste disposal practices. Specifically, previous sediment remedial investigations and IRM work from 1996 to 2011 was based on sediment characterization where CB and PCBs were the most common impacts detected (Ciba, 2003[6] and AECOM, 2012[7]). These facts imply

[6] Sediment Sampling Report for the Pawtuxet River Former Ciba-Geigy Facility, Cranston, Rhode Island, Ciba Specialty Chemicals, May 2003.
[7] Sediment Interim Remedial Measures Report, AECOM, March 2012.

that the source for the shallow impacts is in large part not from impacted groundwater discharge, but from previously known impacted river sediments.

3) The ORP indicates an oxidizing environment is present at all river monitoring locations. The highest DO and ORP is associated with location PZ-02DR, which has the lowest concentrations of COCs.

5.3.2 Remedy Performance Monitoring Plan

The remedy performance-monitoring plan includes the following scheduled components:

- Field parameters in TW-series wells.
- PRB-affected groundwater quality from PZ-8i.
- Groundwater migration water quality from river piezometers.
- Surface water quality.
- Water level readings from representative wells and piezometers.
- Sock weight monitoring (at least every 3 weeks until a defined trend is established).
- AAKP sock deterioration and replacement with time.

AAKP was installed in the PRB array on 9/30/2019, except for location TW-2B, in which socks were placed on 11/25/2019 after the DNAPL was cleared from the well. Sock preparation and deployment SOPs are provided in Attachment H.

Since installation, scheduled remedy effectiveness monitoring has been implemented as per the schedule and analyses summarized in **Table 16**.

Table 16
Remedy Monitoring Schedule
Ciba-Geigy RCRA Closure Project

	TW-1A	TW-1B	TW-2A	TW-2B	TW-3A	TW-3B	TW-4A	TW-4B	PZ-8i	PZ-01DR	PZ-01SR	PZ-02DR	PZ-02SR	PZ-03DR	PZ-03SR	SW-01	SW-02
Week 1 (October 7, 2019)																	
Persulfate	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
pH	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sulfate									X	X	X	X	X	X	X	X	X
Week 2 (October 14, 2019)																	
Persulfate	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
pH	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sulfate									X	X	X	X	X	X	X	X	X
Week 4 (October 28, 2019)																	
VOCs									X	X	X	X	X	X	X		
PCBs									X	X	X	X	X	X	X		
Persulfate	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
pH	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sulfate									X	X	X	X	X	X	X	X	X
Week 6 (November 11, 2019)																	
Persulfate	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
pH	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sulfate									X	X	X	X	X	X	X	X	X
Week 9 (December 5, 2019)																	
Persulfate	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
pH	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sulfate									X	X	X	X	X	X	X	X	X
Week 12 (January 9, 2020)																	
VOCs									X	X	X	X	X	X	X		
PCBs									X	X	X	X	X	X	X		
Persulfate	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
pH	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sulfate										X	X	X	X	X	X	X	X
Week 18 (February 19, 2020)																	
VOCs																	
PCBs																	
Persulfate	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
pH	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sulfate	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Week 24 (March 30, 2020)																	
VOCs									X	X	X	X	X	X	X		
PCBs									X	X	X	X	X	X	X		
Persulfate	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
pH	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sulfate									X	X	X	X	X	X	X	X	X
Week 48 (September 17, 2020)																	
VOCs									X	X	X	X	X	X	X		
PCBs									X	X	X	X	X	X	X		
Persulfate	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
pH	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sulfate									X	X	X	X	X	X	X	X	X

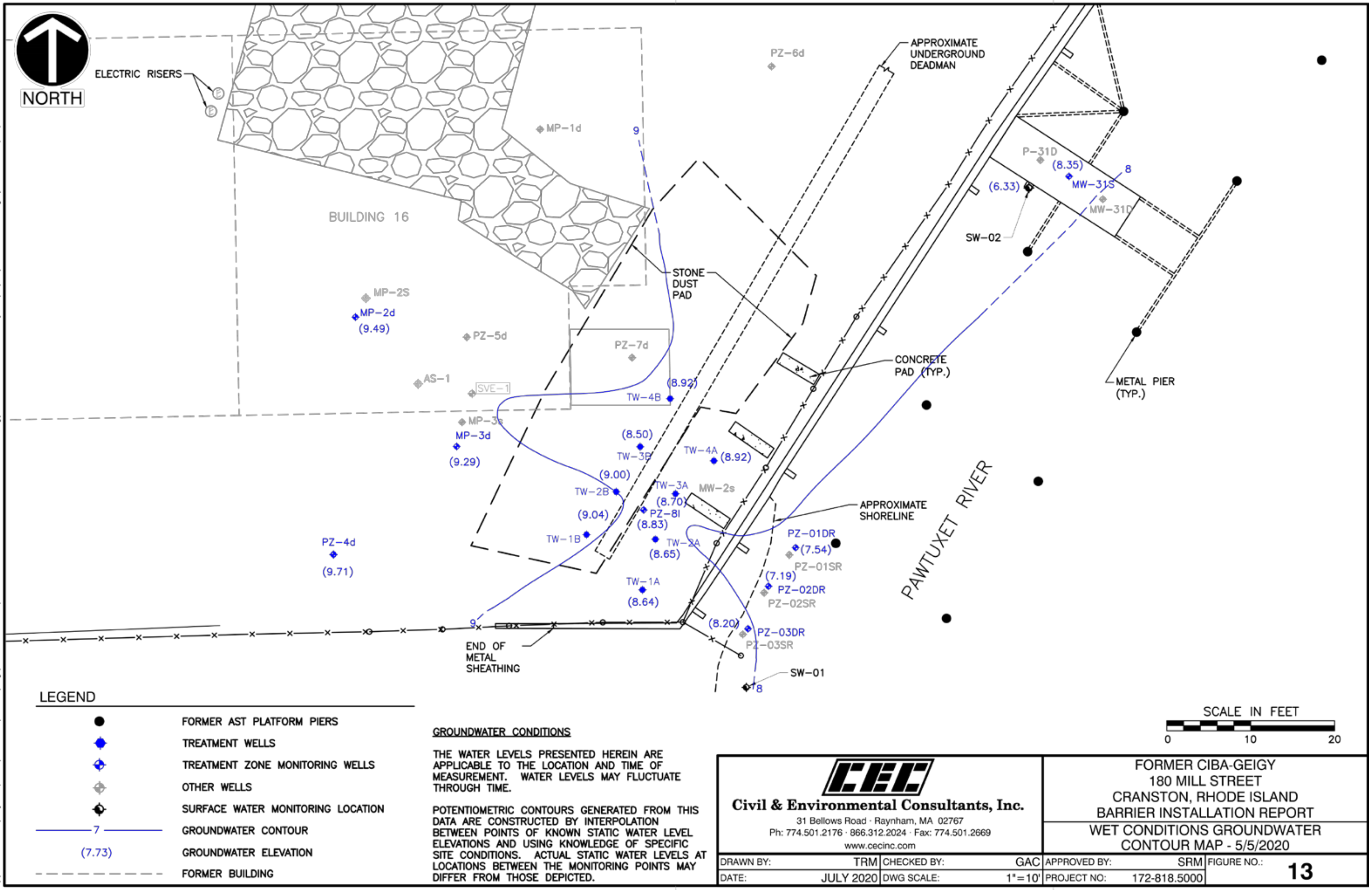
1. VOCs analyzed using USEPA Method 8260C
2. PCB Aroclors analyzed using USEPA Method 8082 after filtering
3. Sulfate analyzed using USEPA Method 9056
4. KP measured using a PeroxyChem field test kit
5. pH, ORP, DO and Turbidity will be monitored in the field using a calibrated pH probe

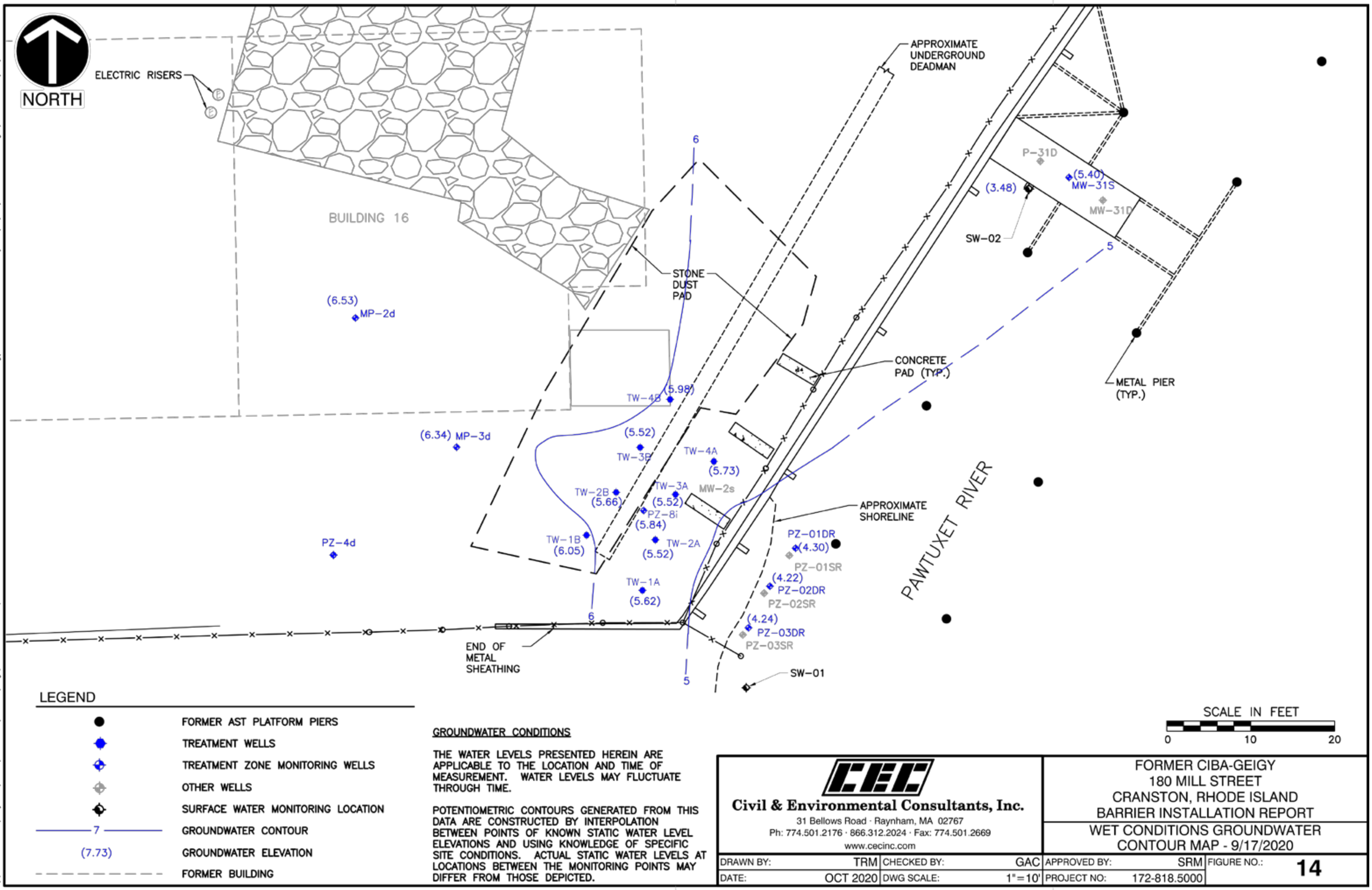
As of this writing, groundwater sampling has been completed and compiled for reporting through week 48 of the schedule, and the data are summarized in subsequent sections of this report.

5.3.3 Groundwater Flow

Since the installation of the PRB wells and associated monitoring infrastructure, in addition to water quality parameters, water levels have been collected to support the characterization of the groundwater flow direction (horizontal and vertical) and magnitude. **Table 17** summarizes the well placement and groundwater gauging data. The potentiometric surface associated with the PRB horizon is shown in F**igures 13** (relatively wet conditions) and **Figure 14** (relatively dry conditions). **Figure 15** provides a cross section through the PRB showing the potentiometric surface and implied groundwater flow lines, in addition to the PRB setting relative to site stratigraphy, physical features (bulkhead, river), and NAPL zone. Finally, **Figure 16** provides a time-series plot of water levels associated with the PRB wells, river piezometers.

A preferential flow pathway appears to exist in the fine silty sand layer below the coarse layer that transports water through the treatment zone. The data supports water movement from the north, west and south towards TW-3B and towards the river, and it supports the interpretation for mass transport reported in AECOM (2016a) [see **Figures 6, 7 and 8**].


NORTH
ELECTRIC RISERS
BUILDING 16
MP-1d
PZ-6d
APPROXIMATE UNDERGROUND DEADMAN
MP-2S
MP-2d
(9.49)
PZ-5d
PZ-7d
AS-1
SVE-1
STONE DUST PAD
CONCRETE PAD (TYP.)
METAL PIER (TYP.)
P-31D
(8.35)
MW-31S
MW-31D
(6.33)
SW-02
(8.92)
TW-4B
MP-3s
MP-3d
(9.29)
(8.50)
TW-3B
TW-4A
(8.92)
(9.00)
TW-2B
TW-3A
MW-2s
(8.70)
(9.04)
PZ-8I
(8.83)
TW-1B
TW-2A
(8.65)
PZ-4d
(9.71)
APPROXIMATE SHORELINE
PZ-01DR
(7.54)
PZ-01SR
(7.19)
PZ-02DR
PZ-02SR
TW-1A
(8.64)
PAWTUXET RIVER
(8.20)
PZ-03DR
PZ-03SR
SW-01
END OF METAL SHEATHING
LEGEND
FORMER AST PLATFORM PIERS
TREATMENT WELLS
TREATMENT ZONE MONITORING WELLS
OTHER WELLS
SURFACE WATER MONITORING LOCATION
7 GROUNDWATER CONTOUR
(7.73) GROUNDWATER ELEVATION
FORMER BUILDING
GROUNDWATER CONDITIONS
THE WATER LEVELS PRESENTED HEREIN ARE APPLICABLE TO THE LOCATION AND TIME OF MEASUREMENT. WATER LEVELS MAY FLUCTUATE THROUGH TIME.
POTENTIOMETRIC CONTOURS GENERATED FROM THIS DATA ARE CONSTRUCTED BY INTERPOLATION BETWEEN POINTS OF KNOWN STATIC WATER LEVEL ELEVATIONS AND USING KNOWLEDGE OF SPECIFIC SITE CONDITIONS. ACTUAL STATIC WATER LEVELS AT LOCATIONS BETWEEN THE MONITORING POINTS MAY DIFFER FROM THOSE DEPICTED.
SCALE IN FEET
0 10 20
CEC
Civil & Environmental Consultants, Inc.
31 Bellows Road · Raynham, MA 02767
Ph: 774.501.2176 · 866.312.2024 · Fax: 774.501.2669
www.cecinc.com
FORMER CIBA-GEIGY
180 MILL STREET
CRANSTON, RHODE ISLAND
BARRIER INSTALLATION REPORT
WET CONDITIONS GROUNDWATER CONTOUR MAP - 5/5/2020
DRAWN BY: TRM
CHECKED BY: GAC
APPROVED BY: SRM
FIGURE NO.: 13
DATE: JULY 2020
DWG SCALE: 1"=10'
PROJECT NO: 172-818.5000


NORTH
ELECTRIC RISERS
BUILDING 16
APPROXIMATE UNDERGROUND DEADMAN
STONE DUST PAD
CONCRETE PAD (TYP.)
METAL PIER (TYP.)
APPROXIMATE SHORELINE
PAWTUXET RIVER
END OF METAL SHEATHING
6
5
(6.53) MP-2d
(6.34) MP-3d
PZ-4d
TW-4B (5.98)
(5.52) TW-3B
TW-4A (5.73)
TW-3A (5.52)
MW-2s
TW-2B (5.66)
PZ-8i (5.84)
TW-1B (6.05)
TW-2A (5.52)
TW-1A (5.62)
PZ-01DR (4.30)
PZ-01SR
(4.22) PZ-02DR
PZ-02SR
(4.24) PZ-03DR
PZ-03SR
SW-01
SW-02
(3.48)
P-31D
(5.40) MW-31S
MW-31D
SCALE IN FEET
0
10
20
LEGEND
FORMER AST PLATFORM PIERS
TREATMENT WELLS
TREATMENT ZONE MONITORING WELLS
OTHER WELLS
SURFACE WATER MONITORING LOCATION
7 GROUNDWATER CONTOUR
(7.73) GROUNDWATER ELEVATION
FORMER BUILDING
GROUNDWATER CONDITIONS
THE WATER LEVELS PRESENTED HEREIN ARE APPLICABLE TO THE LOCATION AND TIME OF MEASUREMENT. WATER LEVELS MAY FLUCTUATE THROUGH TIME.
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FORMER CIBA-GEIGY
180 MILL STREET
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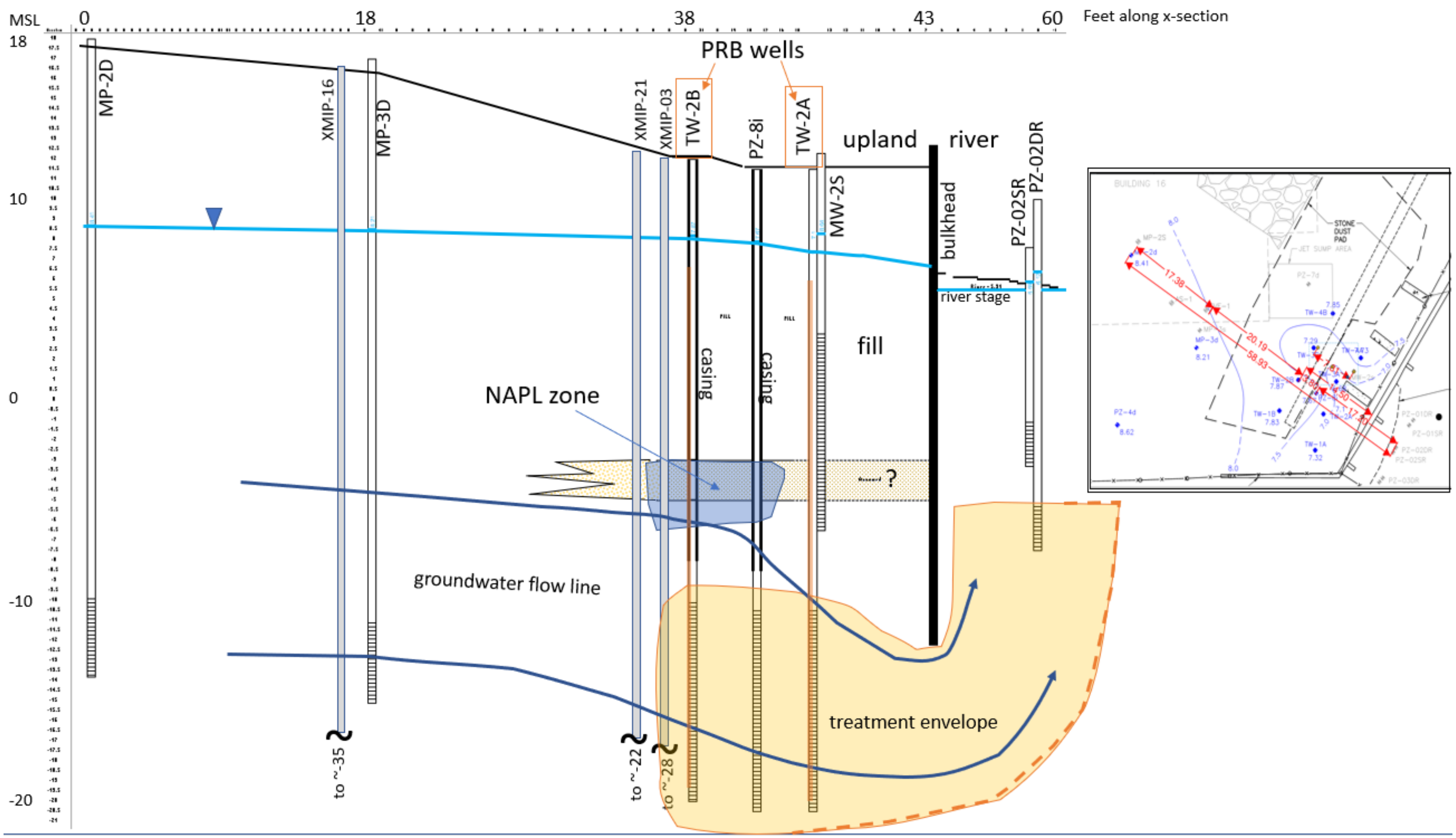
BARRIER INSTALLATION REPORT
WET CONDITIONS GROUNDWATER CONTOUR MAP - 9/17/2020
DRAWN BY: TRM
CHECKED BY: GAC
APPROVED BY: SRM
FIGURE NO.: 14
DATE: OCT 2020
DWG SCALE: 1"=10'
PROJECT NO: 172-818.5000

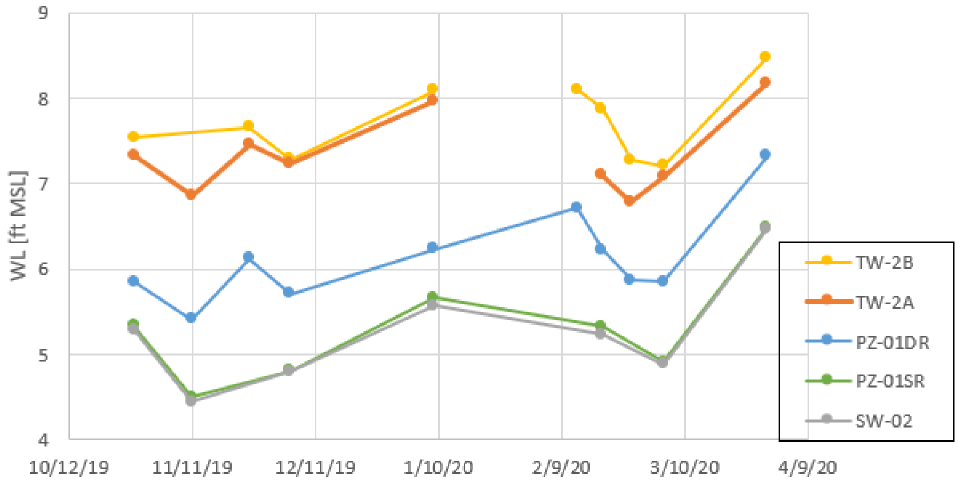
Figure 15
Cross Section Through the PRB Showing MIP Locations
Ciba-Geigy RCRA Closure Project

*



Cross section through the PRB showing MIP locations, well placements, NAPL zone, water levels (2/19/20 event) and implied flow lines and treatment envelope. The hydraulic gradient between TW-2A and PZ-02DR is ~0.04.

Figure 16
Potentiometric Surface Profile Through the PRB Area
Ciba-Geigy RCRA Closure Project



Typical water level data from upland (TW-2B, TW-2A) to under river (PZ-01D, PZ-01S) to river stage (SW-02), showing a groundwater discharge profile consistent with Figure 11.

Table 17
Groundwater Elevation Data
Ciba-Geigy RCRA Closure Project

	Monitoring Wells																	River
	TW-1A	**TW-1B**	**TW-2A**	**TW-2B**	**TW-3A**	**TW-3B**	**TW-4A**	**TW-4B**	**PZ-4d**	**PZ-8i**	**MP-1i**	**MP-2d**	**MP-3d**	**MW-31S**	**PZ-01DR**	**PZ-02DR**	**PZ-03DR**	**SW-02**
Casing Elevation	11.63	11.23	10.88	11.66	11.81	11.38	11.14	11.90	14.27	11.21	13.09	17.84	16.59	15.36	8.23	9.68	10.47	16.43
Well Depth	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	22.00	32.00	32.00	25.50	18.00	18.00	18.00	-
Top of Screen Elevation	352136.11	-10.77	-11.12	-10.34	-10.19	-10.62	-10.86	-10.10	-12.73	-10.79	-4.91	-10.16	-11.41	-5.14	-6.77	-5.32	-4.53	
Well Depth Elevation	352126.11	-20.77	-21.12	-20.34	-20.19	-20.62	-20.86	-20.10	-17.73	-20.79	-8.91	-14.16	-15.41	-10.14	-9.77	-8.32	-7.53	-
Easting	352116.11	352109.41	352117.65	352112.98	352120.05	352115.84	352124.63	352119.41	352079.29	352116.31	352103.89	352081.85	352094.01	352166.94	352134.37	352131.14	352128.69	-
Northing	248725.41	248731.96	248731.46	248737.09	248736.85	248742.45	248740.78	248748.18	248729.62	248734.89	248780.01	248757.88	248742.47	248774.65	248730.41	248725.84	248720.77	-
9/28/2019																		
Depth to Water	5.20	4.65	--	--	5.53	4.41	4.25	5.25	--	--	--	--	--	--	--	--	--	--
Elevation	6.43	6.58	--	--	6.28	6.97	6.89	6.65	--	--	--	--	--	--	--	--	--	--
10/14/2019																		
Depth to Water	5.50	5.70	4.67	5.02	5.45	4.98	4.51	5.43	--	5.60	--	--	--	--	--	--	--	--
Elevation	6.13	5.53	6.21	6.64	6.36	6.4	6.63	6.47	--	5.61	--	--	--	--	--	--	--	--
10/28/2019																		
Depth to Water	4.42	3.59	3.56	4.12	4.52	4.11	3.64	4.53	--	4.49	--	--	--	--	2.38	4.33	4.43	11.14
Elevation	7.21	7.64	7.32	7.54	7.29	7.27	7.5	7.37	--	6.72	--	--	--	--	5.85	5.35	6.04	5.29
11/25/2019																		
Depth to Water	4.40	3.56	3.43	4.00	4.40	4.12	3.51	4.34	6.11	1.82	8.88	9.84	8.79	8.37	2.11	3.70	4.44	11.15
Elevation	7.23	7.67	7.45	7.66	7.41	7.26	7.63	7.56	8.16	9.39	4.21	8.00	7.80	6.99	6.12	5.98	6.03	5.28
12/5/2019																		
Depth to Water	4.50	3.72	3.65	4.38	4.54	4.28	3.76	4.46	--	3.91	--	--	--	--	2.52	4.62	4.83	11.63
Elevation	7.13	7.51	7.23	7.28	7.27	7.10	7.38	7.44	--	7.30	--	--	--	--	5.71	5.06	5.64	4.80
1/9/2020																		
Depth to Water	3.72	2.87	2.92	3.57	3.70	3.23	2.92	3.56	--	3.20	--	--	--	--	2.00	3.64	4.45	10.86
Elevation	7.91	8.36	7.96	8.09	8.11	8.15	8.22	8.34	--	8.01	--	--	--	--	6.23	6.04	6.02	5.57
2/13/2020																		
Depth to Water	3.87	3.11	3.24	3.56	3.90	3.55	3.02	3.74	5.53	3.27	8.32	9.29	8.22	--	1.52	3.03	3.81	10.46
Elevation	7.76	8.12	7.64	8.10	7.91	7.83	8.12	8.16	8.74	7.94	4.77	8.55	8.37	--	6.71	6.65	6.66	5.97
2/19/2020																		
Depth to Water	4.31	3.40	3.78	3.79	5.13	4.09	3.41	4.05	5.65	3.54	8.56	9.43	8.38	--	2.01	3.56	4.31	11.12
Elevation	7.32	7.83	7.10	7.87	6.68	7.29	7.73	7.85	8.62	7.67	4.53	8.41	8.21	--	6.22	6.12	6.16	5.31
2/26/2020																		
Depth to Water	4.76	3.84	4.09	4.39	5.66	4.60	3.98	4.56	5.94	3.95	8.94	9.75	8.72	8.42	2.36	3.91	6.71	11.50
Elevation	6.87	7.39	6.79	7.27	6.15	6.78	7.16	7.34	8.33	7.26	4.15	8.09	7.87	6.94	5.87	5.77	3.76	4.93
3/5/2020																		
Depth to Water	4.70	4.02	3.80	4.45	5.41	4.45	3.89	4.49	-	4.90	-	-	-	-	2.38	3.95	4.75	11.55
Elevation	6.93	7.21	7.08	7.21	6.40	6.93	7.25	7.41	-	6.31	-	-	-	-	5.85	5.73	5.72	4.88
3/30/2020																		
Depth to Water	3.43	2.81	2.71	3.19	-	3.34	2.68	3.30	4.98	2.75	7.78	8.73	7.66	-	0.91	2.50	3.26	9.96
Elevation	8.20	8.42	8.17	8.47	-	8.04	8.46	8.60	9.29	8.46	5.31	9.11	8.93	-	7.32	7.18	7.21	6.47
4/16/2020																		
Depth to Water	2.28	1.49	1.41	2.03	3.53	2.15	1.47	2.17	4.01	1.63	6.90	7.75	6.64	-	-	-	-	8.52
Elevation	9.35	9.74	9.47	9.63	8.28	9.23	9.67	9.73	10.26	9.58	6.19	10.09	9.95	-	-	-	-	7.91
5/5/2020																		
Depth to Water	2.99	2.19	2.23	2.66	3.11	2.88	2.22	2.98	4.56	2.38	7.49	8.35	7.30	7.01	0.69	2.49	2.27	10.10
Elevation	8.64	9.04	8.65	9.00	8.70	8.50	8.92	8.92	9.71	8.83	5.60	9.49	9.29	8.35	7.54	7.19	8.20	6.33
5/19/2020																		
Depth to Water	3.93	3.14	3.24	3.64	4.02	3.83	3.19	3.88	5.46	3.37	8.52	9.27	8.22	7.97	1.90	3.50	4.28	11.12
Elevation	7.70	8.09	7.64	8.02	7.79	7.55	7.95	8.02	8.81	7.84	4.57	8.57	8.37	7.39	6.33	6.18	6.19	5.31
5/28/2020																		
Depth to Water	4.34	3.56	3.67	4.03	4.44	4.22	3.56	4.27	-	3.77	-	-	-	-	-	-	-	-
Elevation	7.29	7.67	7.21	7.63	7.37	7.16	7.58	7.63	-	7.44	-	-	-	-	-	-	-	-
9/17/2020																		
Depth to Water	6.01	5.18	5.36	6.00	6.29	5.86	5.41	5.92	-	5.37	-	11.31	10.25	9.96	3.93	5.46	6.23	12.95
Elevation	5.62	6.05	5.52	5.66	5.52	5.52	5.73	5.98	-	5.84	-	6.53	6.34	5.40	4.30	4.22	4.24	3.48

All Elevations in NAD 1983
-- = Not Measured
2/19/2020 - River Piezometers not measured due to high water
Gray Data not used for creating contour maps

Based on the data discussed in Sections 4.1.3 and 4.3.1, the hydraulic conductivity of the aquifer subject to the PRB influence ranges from 2 to 75 feet/d. An additional K-estimate was derived based on a rising and falling head slug test performed at performance monitoring well PZ-8i situated within the PRB. The data were analyzed using the Bower-Rice method (**Appendix D**), and the conductivity determined by the falling head test was $1.0x10^{-4}$ cm/sec (0.28 feet/day) and by the rising head test was $1.0x10^{-4}$ cm/sec (0.28 feet/day). This value is consistent with the well log description of the screened interval, where the medium is described as “fine sand and silt”.

5.3.4 Performance Monitoring Data

Table 16 provides the performance-monitoring plan. As of this writing, sampling through week 48 (September 17, 2020) has been completed and reported herein. The data, described below, are grouped as follows: TW-series, PZ-8i, river piezometers, surface water and PRB well maintenance.

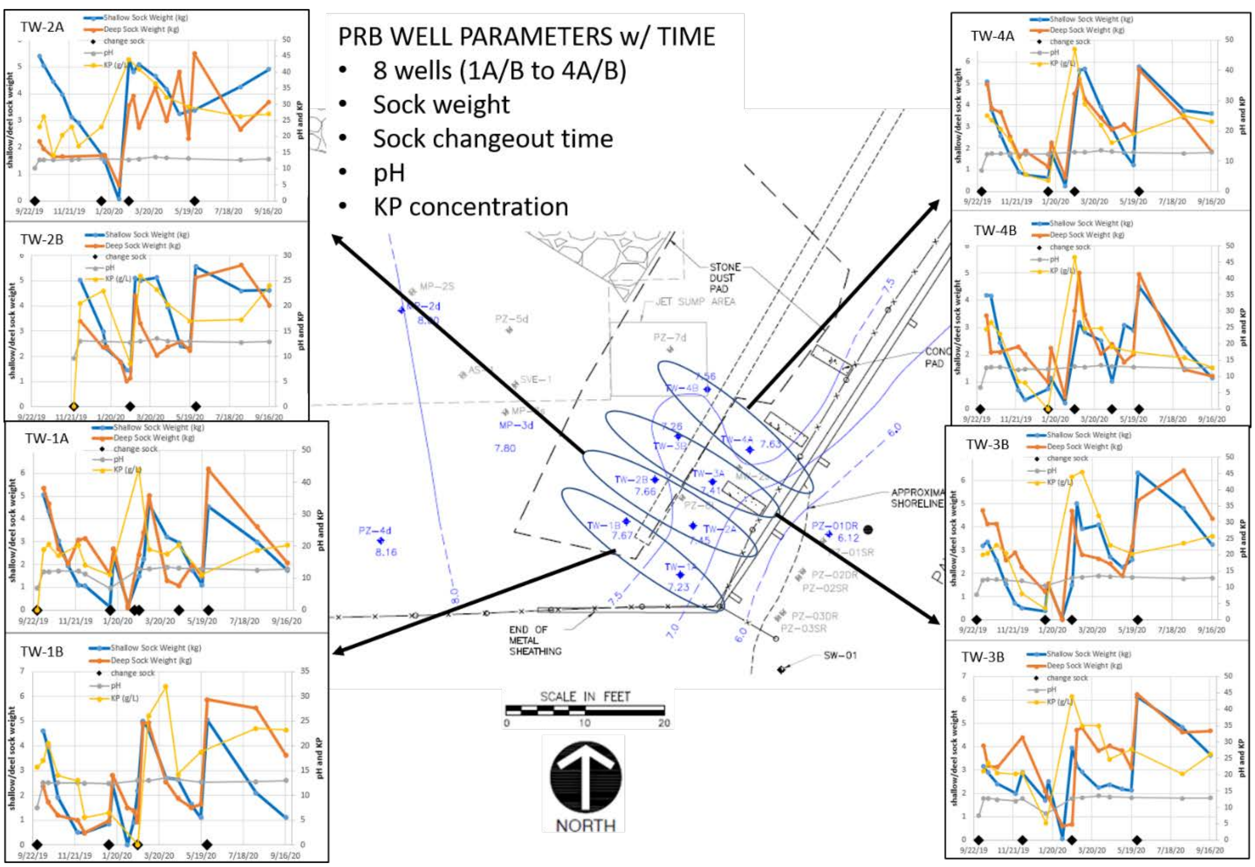
5.3.4.1 TW-Series

Table 18 provides a summary of the TW-series data and **Figures 17** and **18** provide a graphical representation. The treatment wells are sampled for field parameters only, without purging, using a submersible pump. The pump inlet was set at approximately the center of the well screen. In addition, the AAKP degradation rate is assessed through both reduction in sock weight and change in field parameters with time. Below is a summary of the data collected to date:

1. pH: Maintained at approximately 12, which is optimal for KP activation and effectiveness.
2. DO: Maintained at levels at or above solubility. This is an indication that the activated KP is dissociating and adding oxygen to the groundwater.
3. ORP: Maintained at highly oxidative conditions (>300 eV), as expected by the KP dissociation.

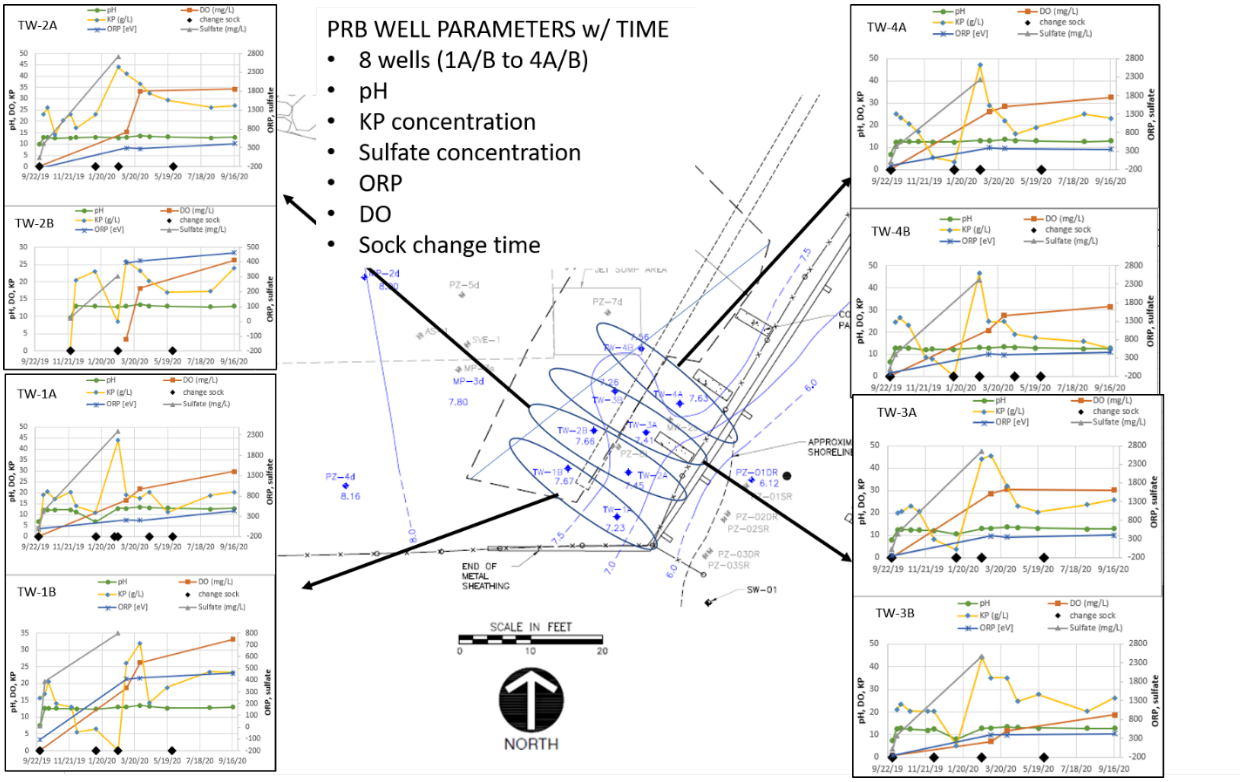
4. KP: Maintained at optimal levels > 20 g/L. The change in KP concentration with time provides an indication for sock replacement. See **Section 5.3.4.5** for a discussion on sock maintenance.
5. Sock weight: The AAKP socks are weighed while submerged in the water and weigh approximately 5 kilograms when filled. The change in weight over time is an indicator of sock depletion and changeout. Sock are renewed every 3 to 5 months. See Section 5.3.4.5 for a discussion on sock maintenance.

Figure 17
Time Trend in TW-Series Wells, Sock Weight, pH and KP
Ciba-Geigy RCRA Closure Project



AAKP upper/lower sock weight, pH and KP concentration. Timing of sock renewal shown. The pH and KP levels are maintained at optimal levels. The observed parameter trends shown implies that each PRB well has equivalent connection to the mobile fraction of the aquifer.

Figure 18
Time Trend in TW-Series Wells, Groundwater Quality Parameters
Ciba-Geigy RCRA Closure Project



pH and KP and sulfate concentrations, ORP and DO. Timing of sock renewal shown. Parameters show KP disassociation and favorable oxidation environment.

5.3.4.2 Piezometer PZ-8i

Recall that PZ-8i is a performance monitoring point located within the PRB. **Table 19** provides a summary of the analytical data collected to date and **Figure 19** provides a graphical representation of the water quality data.

Samples are collected from PZ-8i by purging the well of three well volumes using a submersible pump with the pump elevation set at the middle of the screened interval. During purging, water quality parameters, including DO, conductivity, temperature, pH and ORP are monitored using a flow through cell.

Table 19

Piezometer PZ-8I VOC Monitoring Data

Ciba-Geigy RCRA Closure Project

COCs	10/2/2019	10/28/2019	1/9/2020	3/30/2020	9/17/2020
1,2-DCB	**2,290**	**20,500 E**	**736**	**40,700**	**20,600**
CB	314	**4,800**	524	**8,450**	**6,190**
2-CT	6.8	84.8	3.5	154	80.7
Tol	13.5	167	20.7	172	175
Xyl	3.6	43.7	< 3.1	92.2	23.2
PCB	**2.72**	< 0.09	**1.72**	**4.7**	**< 1**
Field Parameters					
Persulfate	0	0	0	0	0
Sulfate	22	13.3	108	285	320
pH	6.76	7.18	10.26	5.86	5.95
DO	0.1	0.2	12.5	3.6	0.23
ORP	-97.6	-45.5	97.3	16.4	-39.2

1,2-DCB = 1,2-Dichlorobenzene

CB = Chlorobenzene

2-CT = 2 Chlorotoluene

Tol = Toluene

Xyl = Total Xylenes

PCB = Total Polychlorinated Biphenyl

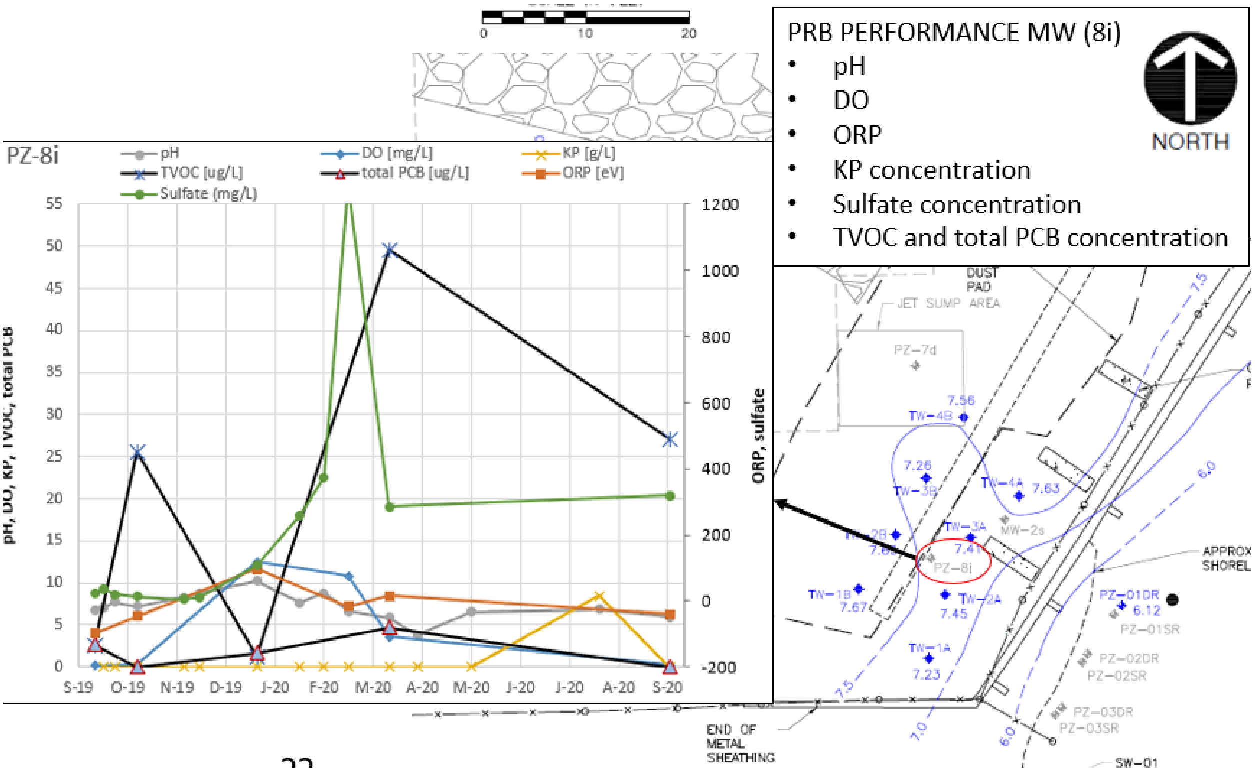
All COC data is reported in µg/L

KP data is reported in g/L

Sulfate and DO data is reported in mg/L

Bold values are greater than their respect MPS or MCL

Figure 19
Water Quality Time Trend in PZ-8i
Ciba-Geigy RCRA Closure Project



pH, ORP, DO and KP and sulfate TVOC and total PCB concentration. There is a modest indication of reagent transport starting in January, with elevated sulfate persisting with time.

As expected, 1,2-DCB is the dominant compound based on upland media characterization. In addition, the effect of the AAKP amendment on water quality is apparent as of the January 9, 2020 sampling event, with a significant increase in pH, sulfate, DO and ORP and a decrease in COC content. It is noted that this well is located down-gradient of TW-2B, in which AAKP was not installed until November 25, 2019 due to the presence of NAPL. Subsequent sample events show only a sustained sulfate level. It is noted that PZ-8i has observed NAPL infiltration, and it has a poor apparent connection with the aquifer based on the slug test data. These attributes must be considered when interpreting the data at this well.

5.3.4.3 River Piezometers

The groundwater was sampled from the river piezometers as per the **Table 16** schedule. The groundwater samples are collected using a peristaltic pump through dedicated down-hole tubing with the opening approximately at the center of the well screen. The river piezometers provide Site-related groundwater quality data before Site-related groundwater discharges to the river. The analytical results for the deep and shallow series piezometers are summarized in **Tables 20** and **21**, respectively.

Table 20

Deep River Piezometer VOC Monitoring Data

Ciba-Geigy RCRA Closure Project

	PZ-01DR					PZ-02DR					PZ-03DR				
COCs	**10/16/19 (baseline)**	**10/28/2019**	**1/9/2020**	**3/30/2020**	**9/17/2020**	**10/16/19 (baseline)**	**10/28/2019**	**1/9/2020**	**3/30/2020**	**9/17/2020**	**10/16/19 (baseline)**	**10/28/2019**	**1/9/2020**	**3/30/2020**	**9/17/2020**
1,2-DCB	**4,480**	**4,510**	**4,580**	**5,240**	**6,120**	<1	2.4	<1	<1	<1	28.2	12.9	26.9	18.2	16.3
CB	233	57.9	36.4	49.9	54.6	26.3	38.4	11.3	3.2	<1	559	144	219	250	256
2-CT	6.4	1.1	<1	< 1	< 1	<1	1.3	<1	<1	<1	9.2	3.2	<1	<1	< 1
Tol	3.5	2.1	1.4	1.6	1.4	<1	1.4	<1	<1	<1	1.5	<1.0	<1	<1	< 1
Xyl	9.5	5.1	4.5	4.65	< 2	<2	<3	<3	<2	<2	4.6	<3	<3	< 2	< 2
PCB	<0.10	< 0.11	<0.11	< 0.09	**< 1**	0.16	0.23	< 0.11	< 0.11	**<1**	0.41	<0.10	0.18	< 0.09	**< 1**
Field Parameters															
Persulfate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sulfate	<5.0	5.2	<5.0	<5.0	300	26.4	26.3	< 5.0	< 5.0	67	13	15.4	<5.0	<5.0	8.9
pH	6.99	6.96	8.52	7.54	6.67	6.85	7.35	7.59	9.6	6.98	7.14	7.01	6.43	6.55	7.03
DO	0.31	0.03	9.67	1.07	3.50	1.22	0.02	9.4	1.16	5.19	0.37	0.03	10.16	1.93	3.36
ORP	135.3	-450.3	-26.9	-196.7	316.3	195.8	-503.2	24.1	-97.3	158.1	161.9	-472.2	10.9	-69.4	-111.8

1,2-DCB = 1,2-Dichlorobenzene

CB = Chlorobenzene

2-CT = 2 Chlorotoluene

Tol = Toluene

Xyl = Total Xylenes

PCB = Total Polychlorinated Biphenyls

All COC data is reported in µg/L

Persulfate data is reported in g/L

Sulfate and DO data is reported in mg/L

Bold values are greater than their respect MPS or MCL

Table 21

Shallow River Piezometer VOC Monitoring Data

Ciba-Geigy RCRA Closure Project

	PZ-01SR					PZ-02SR					PZ-03SR				
COCs	**10/16/19 (baseline)**	**10/28/2019**	**1/9/2020**	**3/30/2020**	**9/17/2020**	**10/16/19 (baseline)**	**10/28/2019**	**1/9/2020**	**3/30/2020**	**9/17/2020**	**10/16/19 (baseline)**	**10/28/2019**	**1/9/2020**	**3/30/2020**	**9/17/2020**
1,2-DCB	**336**	7.4	**428**	**690**	**668**	**98**	27.8	83	82.4	**97**	**656**	**322**	**204**	**308**	**287**
CB	**9,070**	220	**3,520**	**5,050**	**4,250**	**4,680**	254	**1,900**	**2,160**	**5,320**	**2,380**	673	523	884	742
2-CT	60.5	2.5	23.7	25.5	8.6	34.2	2.3	7.6	2.7	12.2	7.7	2.1	< 1	< 1	1.1
Tol	37.5	1.4	2.9	1.3	1.2	8.6	1.3	1.5	< 1	< 1	1.2	1.3	< 1	1	< 1
Xyl	45.7	<3	7.9	7	< 2	14.3	<3	<4	< 3	< 2	<3.4	< 3	<3	< 3	< 3
PCB	**1.84**	<0.09	0.38	**0.5**	**2.99**	**1.81**	**8.77**	**4.34**	0.18	**< 1**	**1**	<0.09	**0.97**	<0.09	**< 1**
Field Parameters															
Persulfate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sulfate	36.5	25.9	12.9	20.8	39.5	37.5	34	17.1	21.1	45.5	<5.0	<5.0	<5.0	6.5	53.5
pH	6.85	6.78	7.37	6.75	6.86	7.14	6.81	6.71	6.46	6.62	6.83	6.88	6.57	6.65	7.32
DO	0.4	0.24	9.43	2.69	0.21	0.33	1.61	10.86	2.9	0.17	0.39	0.12	10.55	3.28	0.28
ORP	183.4	-306	12.3	-41.4	131.1	145.9	-192	33	-40.4	-201.1	154.7	-388.5	21.3	-101.2	-180.2

1,2-DCB = 1,2-Dichlorobenzene

CB = Chlorobenzene

2-CT = 2 Chlorotoluene

Tol = Toluene

Xyl = Total Xylenes

PCB = Total Polychlorinated Biphenyls

All COC data is reported in µg/L

Sulfate and DO data is reported in mg/L

Persulfate data is reported in g/L

Bold values are greater than their respect MPS or MCL

The analytical data are consistent with that described in Section 5.3.1 for the baseline data (no significant change). With regard to field parameters, there is an indication of PRB influence through the observed trends in pH, DO and ORP.

The PRB was installed on September 30, 2019 (except for TW-2A installed on November 25, 2019), and given the distance between the PRB and the river piezometers (approximately 20 feet) and a groundwater seepage velocity of approximately 0.27 feet/day (K approximately 2 ft/d, i approximately 0.04 and porosity approximately 0.3), PRB influence of the deeper piezometers is expected in approximately 75 days, which is when the PRB indicator parameters are observed.

5.3.4.4 Surface Water

The surface water is being monitored for river stage to support the hydrology characterization and for KP, sulfate and pH to evaluate if there are impacts from the AAKP treatment system. **Table 22** contains the results of the surface water screening.

Table 22
Surface Water Monitoring Data
Ciba-Geigy RCRA Closure Project

Location	Date	pH	Persulfate (g/L)	Sulfate (mg/L)
SW-01	9/26/2019	--	--	27.9
	10/7/2019	8.47	0.0	27.9
	10/14/2019	7.75	0.0	19.3
	10/28/2019	8.55	0.0	14.7
	11/11/2019	8.79	0.0	17.3
	12/5/2019	7.54	0.0	18.7
	1/9/2020	--	0.0	12.4
	2/19/2020	9.37	0.0	12.8
	3/30/2020	7.08	0.0	15.1
	9/17/2020	7.10	0.0	38.0
SW-02	10/7/2019	8.06	0.0	27.7
	10/14/2019	8.01	0.0	19.7
	10/28/2019	9.34	0.0	15.2
	11/11/2019	7.35	0.0	18.5
	12/5/2019	7.52	0.0	19.6
	1/9/2020	--	0.0	12.2
	2/19/2020	9.18	0.0	13.2
	3/30/2020	6.77	0.0	11.9
	9/17/2020	6.99	0.0	44.0

Location SW-01 is upstream of the river piezometers and location SW-02 is downstream of the treatment area on the MW-31s platform. The sulfate, KP and pH data from the upstream and downstream locations are qualitatively the same, and thus, there is thus far no indication of PRB influence.

5.3.4.5 PRB Maintenance

PRB maintenance consists of refreshing the installed socks in each individual well based on change in weight (i.e., the socks become lighter as the AAKP dissolves) and KP concentration (i.e., the in-well KP concentration declines in the limit as the AAKP dissolves and disassociates. **Figure 17** provides PRB time-series plots with sock weight and KP concentration, as well as, pH. **Appendix F** provides the SOP for PRB sock maintenance.

6.0 SUMMARY AND RECOMMENDATIONS

This report described the design, installation, monitoring and maintenance of a PRB intended to control migration of groundwater impacted with Site-related COCs (dissolved-phase MPS compounds and PCBs).

To support design, a predesign investigation was implemented, and it included the following components:

1. Profile study – Use of MiHpt technology to generate vertical profiles of both in-situ contaminant mass and hydraulic conductivity and define zones in the aquifer that support significant mass flux (hydraulic conductivity times dissolved-phase concentration), which are the target for the PRB application (**Section 4.1**). Once identified, groundwater grab samples were collected to quantify the magnitude of the mass flux (**Section 4.1.2**).
2. PRB preinstallation study – The MiHpt data showed a major mass flux zone at and downgradient of the XMIP-03 location. Because NAPL was detected in a specific horizon, an additional boring program was implemented to delineate the NAPL zone in an effort to position the PRB downgradient of the apparent source area (**Section 4.1.2.1**).
3. Correlation of the MiHpt data with the Site's extensive soil, groundwater and sediment database was used to derive a CSM for groundwater flow and transport (**Sections 4.1.4 and 4.4**).
4. Bench Study – AAKP treatment of impacted Site soils and groundwater was analyzed in a laboratory setting to determine AAKP oxidant demand and dissolved-phase in-situ contaminant degradation dynamic. The data support AAKP recipe and contaminant attenuation and required contaminant contact time (**Section 4.2**).

Completion of the pre-design tasks listed above provided a basis for PRB geometry (width and depth normal to groundwater flow, and thickness parallel to groundwater flow), appropriate performance monitoring infrastructure and sampling plan, and PRB maintenance plan.

Based on the above referenced data, an eight well PRB network was installed (**Section 5**) and charged with AAKP deployed in socks and monitoring points intended to intercept groundwater that is affected by the PRB were installed. PRB maintenance is described in **Appendix I** and the performance-monitoring schedule and parameter set is described in **Section 5.3.2**. A total of 48 weeks of monitoring was completed and is described in this report.

6.1 RECOMMENDATIONS.

Based on the data collected to date, the AAKP deployed in the PRB wells is providing the necessary chemistry to destroy the dissolved-phase COCs (**Section 5.3.4.1**), and based on the observed AAKP dissolution rate and water level data, the PRB is in hydraulic communication with the affected aquifer. However, the monitoring network is less than adequate to fully assess performance, and the following recommendations are made:

1. Based on slug test data, PZ-8i is not hydraulically connected to the aquifer.
2. The deep river piezometers are not deep enough to best monitor mass transport under the bulkhead.
3. The furthest downgradient river piezometer, PZ-01DR, is recording the highest MPS concentrations associated with discharging groundwater; therefore at least one more monitoring point is required to document the sufficiency of the lateral extent of the PRB.

Given these monitoring issues, the following recommendations are made:

1. Redevelop well PZ-8i to attempt to clear it of NAPL and improve hydraulic connection.
2. Conduct slug tests at select PRB wells to assess hydraulic connection and the spatial variation of aquifer hydraulic conductivity.
3. Augment the performance-monitoring network by installing deeper monitoring intervals adjacent to and spanning across the depth of the sheet-pile bulkhead.
4. To verify the adequacy of the PRB lateral extent install include with recommendation (3.) an additional monitoring point or more additional downstream of PZ-01DR as appropriate.

APPENDIX A
COLUMBIA ANALYTICAL REPORT

APPENDIX B
GROUNDWATER PURGING FIELD PARAMETERS SUMMARY

Well ID	TW-1A																	
Date:	9/28/2019	10/7/2019	10/14/2019	10/28/2019	11/11/2019	11/25/2019	12/5/2019	1/9/2020	1/14/2020	2/4/2020	2/19/2020	2/26/2020	3/5/2020	3/30/2020	4/16/2020	5/5/2020	5/19/2020	5/28/2020
Depth to water	5.20	--	5.50	4.42	4.94	4.40	4.50	3.72	--	--	4.31	4.76	4.70	3.43	2.28	2.99	3.93	4.34
pH	6.80	12.03	12.07	12.28	--	12.18	11.23	6.83	--	--	12.82	--	12.85	13.42	13.11	--	12.95	--
Temperature °C	16.1	19.8	15.0	13.2	--	12.4	11.5	6.1	--	--	8.5	--	9.8	10.0	11.1	--	14.6	--
Dissolved Oxygen (mg/L)	0.14	--	--	--	--	--	--	--	--	--	--	--	16.64	21.66	--	--	--	--
Oxidation Reduction Potential (ORP)	-14.8	--	--	--	--	--	--	--	--	--	--	--	204.7	202.9	--	--	--	--
Klozur Persulfate (g/L)	--	19.0	20.5	17.0	--	20.3	14.0	11.0	--	--	44.0	--	19.0	17.5	20.25	--	11.10	--
Sulfate (mg/L)	16.80	425	--	--	--	--	--	--	--	--	2,400	--	--	--	--	--	--	--
Shallow Sock Weight (lbs)	NA	11 lbs 2 oz	9 lbs 9 oz	6 lbs 11 oz	4 lbs 4 oz	2 lbs 8 oz	2lbs 5 oz	5 oz	5 lbs 1oz	0 lbs 7oz	3 lbs 4 oz	4 lbs 15 oz	10 lbs 4oz	7 lbs 1 oz	6 lbs 8 oz	3 lbs 14 oz	2 lbs 7oz	10 lbs 0 oz
Deep Sock Weight (lbs)	NA	11 lbs 13 oz	10 lbs 4 oz	5 lbs 15 oz	4 lbs 8 oz	6 lbs 12 oz	6lbs 15oz	3 lbs 7 oz	5 lbs 15 oz	0 lbs 3 oz	5 lbs 6 oz	7 lbs 7 oz	10 lbs 17 oz	2 lbs 14 oz	2 lbs 6 oz	4 lbs 6 oz	3 lbs 4 oz	13 lbs 10 oz
Shallow Sock Weight (kg)	NA	5.0	4.3	3.0	1.9	1.1	1.1	0.1	2.3	0.2	1.5	2.2	4.6	3.2	2.9	1.8	1.1	4.5
Deep Sock Weight (kg)	NA	5.4	4.6	2.7	2.0	3.1	3.2	1.6	2.7	0.1	2.4	3.4	5.0	1.3	1.1	2.0	1.5	6.2

Well ID	TW-1B																	
Date:	9/28/2019	10/7/2019	10/14/2019	10/28/2019	11/25/2019	12/5/2019	1/9/2020	1/14/2020	2/4/2020	2/13/2020	2/19/2020	2/26/2020	3/5/2020	3/30/2020	4/16/2020	5/5/2020	5/19/2020	5/28/2020
Depth to water	4.65	--	5.70	3.59	3.56	3.72	2.87	--	--	3.11	3.40	3.84	4.02	2.81	1.49	2.19	3.14	3.56
pH	7.44	12.55	12.53	12.56	12.55	12.48	12.35	--	--	--	12.96	--	13.01	13.51	13.17	--	12.95	--
Temperature °C	15.0	17.5	14.5	13.8	12.2	11.6	7.6	--	--	--	10.7	--	10.4	10.8	11.1	--	14.8	--
Dissolved Oxygen (mg/L)	0.13	--	--	--	--	--	--	--	--	--	--	--	18.71	26.26	--	--	--	--
Oxidation Reduction Potential (ORP)	-104.9	--	--	--	--	--	--	--	--	--	--	--	408.4	417.5	--	--	--	--
Klozur Persulfate (g/L)	15.7	17.0	20.5	14.0	13.0	5.5	6.5	--	--	--	0.0	--	26.0	32.0	14.25	--	18.75	--
Sulfate (mg/L)	7.90	388	--	--	--	--	--	--	--	--	800	--	--	--	--	--	--	--
Shallow Sock Weight (lbs)	NA	10 lbs 2 oz	8 lbs 11 oz	4 lbs 3 oz	1 lb 3 oz	1 lb 1 oz	1 lb 14 oz	5 lbs 4 oz	0 lbs 0 oz	2 lbs 0 oz	4 lbs 13 oz	11 lbs 2 oz	10 lbs 5 oz	6 lbs 0 oz	5 lbs 13 oz	3 lbs 10 oz	2 lbs 7 oz	11 lbs 2 oz
Deep Sock Weight (lbs)	NA	5 lbs 3 oz	3 lbs 13 oz	2 lbs 10 oz	2 lbs 5 oz	1 lb 1 oz	2 lb 2 oz	6 lbs 3 oz	3 lbs 5 oz	3lbs 1oz	2 lbs 1 oz	10 lbs 14 oz	10 lbs 14 oz	5 lbs 10 oz	4 lbs 2 oz	3 lbs 5 oz	3 lbs 10 oz	12 lbs 15 oz
Shallow Sock Weight (kg)	NA	4.6	3.9	1.9	0.5	0.5	0.9	2.4	0.0	0.9	2.2	5.0	4.7	2.7	2.6	1.6	1.1	5.0
Deep Sock Weight (kg)	NA	2.4	1.7	1.2	1.0	0.5	1.0	2.8	1.5	1.4	0.9	4.9	4.9	2.6	1.9	1.5	1.6	5.9

Well ID	TW-2A																	
Date:	9/30/2019	10/7/2019	10/14/2019	10/28/2019	11/11/2019	11/25/2019	12/5/2019	1/9/2020	1/14/2020	2/4/2020	2/19/2020	2/26/2020	3/5/2020	3/30/2020	4/16/2020	5/5/2020	5/19/2020	5/28/2020
Depth to water	4.17	--	4.67	3.56	4.02	3.43	3.65	2.92	--	--	3.78	4.09	3.80	2.71	1.41	2.23	3.24	3.67
pH	10.06	12.83	12.80	12.63	--	12.75	12.90	13.08	--	--	12.78	--	13.04	13.65	13.26	--	13.13	--
Temperature °C	13.9	17.6	16.6	14.1	--	12.7	12.0	6.8	--	--	9.7	--	10.40	10.60	11.2	--	13.9	--
Dissolved Oxygen (mg/L)	0.36	--	--	--	--	--	--	--	--	--	--	--	15.20	33.32	--	--	--	--
Oxidation Reduction Potential (ORP)	-239.5	--	--	--	--	--	--	--	--	--	--	--	293.7	280.2	--	--	--	--
Klozur Persulfate (g/L)	--	23.0	26.3	14.0	20.5	23.0	17.0	23.0	--	--	44.0	--	41.0	36.5	32.25	--	29.25	--
Sulfate (mg/L)	34	408	--	--	--	--	--	--	--	--	2,720	--	--	--	--	--	--	--
Shallow Sock Weight (lbs)	NA	11 lbs 14 oz	11 lbs 2 oz	9 lbs 13 oz	8 lbs 12 oz	6 lbs 14 oz	6lbs 7 oz	3 lbs 13 oz	3 lbs 3 oz	0 lbs 2 oz	11 lbs 10 oz	10 lbs 9 oz	11 lbs 4 oz	10 lbs 4 oz	9 lbs 3 oz	7 lbs 2 oz	7 lbs 6 oz	7 lbs 7 oz
Deep Sock Weight (lbs)	NA	4 lbs 14 oz	4 lbs 4 oz	3lbs 10 oz	3 lbs 10 oz	Stuck on bottom	tuck on bottom	tuck on bottom	3 lbs 12 oz	1 lbs 4 oz	7 lbs 13 oz	8 lbs 8 oz	6 lbs 0 oz	9 lbs 5 oz	6 lbs 9 oz	10 lbs 10 oz	5 lbs 2 oz	12 lbs 2 oz
Shallow Sock Weight (kg)	NA	5.4	5.0	4.5	4.0	3.1	2.9	1.7	1.4	0.1	5.3	4.8	5.1	4.6	4.2	3.2	3.3	3.4
Deep Sock Weight (kg)	NA	2.2	1.9	1.6	1.6	--	--	--	1.7	0.6	3.5	3.9	2.7	4.2	3.0	4.8	2.3	5.5

Well ID	TW-2B																	
Date:	*9/30/2019	*10/7/2019	*10/14/2019	*10/28/2019	*11/25/2019	*12/5/2019	*1/9/2020	**1/14/2020	**2/4/2020	** 2/13/2020	*2/19/2020	** 2/26/2020	3/5/2020	*3/30/2020	*4/16/2020	*5/5/2020	**5/19/2020	*5/28/2020
Depth to water	5.61	5.11	5.02	4.12	4.00	4.38	3.57	--	--	3.56	3.79	4.39	4.45	3.19	2.03	2.66	3.64	4.03
pH	--	--	--	--	9.60	13.07	12.98	--	--	--	12.75	--	12.95	13.48	13.05	--	12.95	--
Temperature °C	--	--	--	--	12.4	12.7	5.8	--	--	--	9.0	--	10.6	10.8	10.2	--	14.20	--
Dissolved Oxygen (mg/L)	--	--	--	--	--	--	--	--	--	--	--	--	3.48	18.17	--	--	--	--
Oxidation Reduction Potential (ORP)	--	--	--	--	--	--	--	--	--	--	--	--	394.8	407.0	--	--	--	--
Klozur Persulfate (g/L)	--	--	--	--	0.0	20.5	23.0	--	--	--	8.5	--	26.0	23.25	20.25	--	17.00	--
Sulfate (mg/L)	--	--	--	--	22.6	--	--	--	--	--	305	--	--	--	--	--	--	--
Shallow Sock Weight (lbs)	--	--	--	--	--	11 lbs 1 oz	6 lbs 9 oz	5 lbs 1 oz	3 lbs 15 oz	3 lbs 3 oz	3 lbs 2 oz	11 lbs 5 oz	11 lbs 0 oz	11 lbs 5 oz	8 lbs 11 oz	5 lbs 5 oz	5 lbs 2 oz	12 lbs 4 oz
Deep Sock Weight (lbs)	--	--	--	--	--	7 lbs 8 oz	5 lbs 3 oz	5 lbs 4 oz	3 lbs 14 oz	2 lbs 4 oz	2 lbs 8 oz	9 lbs 10 oz	7 lbs 6 oz	4 lbs 8 oz	5 lbs 4 oz	5 lbs 11 oz	4 lbs 14 oz	11 lbs 15 oz
Shallow Sock Weight (kg)	--	--	--	--	--	5.0	3.0	2.3	1.8	1.4	1.4	5.1	5.0	5.1	3.9	2.41	2.32	5.56
Deep Sock Weight (kg)	--	--	--	--	--	3.4	2.4	2.4	1.8	1.0	1.1	4.4	3.3	2.0	2.4	2.6	2.2	5.1

Well ID	TW-3A																	
Date:	9/28/2019	10/7/2019	10/14/2019	10/28/2019	11/11/2019	11/25/2019	12/5/2019	1/9/2020	1/14/2020	2/4/2020	2/19/2020	2/26/2020	3/5/2020	3/30/2020	4/16/2020	5/5/2020	5/19/2020	5/28/2020
Depth to water	5.53	--	5.45	4.52	4.95	4.40	4.54	3.70	--	--	5.13	5.66	5.41	--	3.53	3.11	4.02	4.44
pH	7.88	12.23	12.51	12.41	12.19	--	11.95	10.47	--	--	12.89	--	13.05	13.57	13.33	--	13.09	--
Temperature °C	17.4	23.0	14.6	12.8	14.6	--	12.8	4.7	--	--	9.7	--	8.9	10.0	10.2	--	13.00	--
Dissolved Oxygen (mg/L)	0.08	--	--	--	--	--	--	--	--	--	--	--	28.60	30.43	--	--	--	--
Oxidation Reduction Potential (ORP)	-151.5	--	--	--	--	--	--	--	--	--	--	--	371.8	347.3	--	--	--	--
Klozur Persulfate (g/L)	--	20.0	20.5	23.0	20.5	--	8.0	3.5	--	--	44.0	--	45.5	32.0	23.0	--	20.25	--
Sulfate (mg/L)	18.80	442	--	--	--	--	--	--	--	--	2,650	--	--	--	--	--	--	--
Shallow Sock Weight (lbs)	NA	7 lbs	7 lbs 7 oz	5 lbs 10 oz	3 lbs 6 oz	1 lbs 7 oz	1 lb 2 oz	13 oz	3 lbs 5 oz	0 lbs 2 oz	3 lbs 5 oz	11 lbs 0 oz	8 lbs 10 oz	9 lbs 0 oz	6 lbs 0 oz	5 lbs 0 oz	5 lbs 11 oz	14 lbs 0 oz
Deep Sock Weight (lbs)	NA	10 lbs 6 oz	9 lbs 2 oz	9 lbs 2 oz	5 lbs 10 oz	6 lbs 8 oz	5 lbs	2 lbs 11 oz	3 lbs 7 oz	0 lbs 0 oz	10 lbs 5 oz	7 lbs 9 oz	6 lbs 4 oz	5 lbs 13 oz	5 lbs 5 oz	4 lbs 2 oz	6 lbs 15 oz	11 lbs 15 oz
Shallow Sock Weight (kg)	NA	3.2	3.4	2.6	1.5	0.7	0.5	0.4	1.5	0.1	1.5	5.0	3.9	4.1	2.7	2.27	2.58	6.35
Deep Sock Weight (kg)	NA	4.7	4.1	4.1	2.6	2.9	2.3	1.2	1.6	0.0	4.7	3.4	2.8	2.6	2.4	1.9	3.1	5.1

Well ID	TW-3B																	
Date:	9/30/2019	10/7/2019	10/14/2019	10/28/2019	11/25/2019	12/5/2019	*1/9/2020	*1/10/2020	** 1/14/2020	** 2/4/2020	*2/19/2020	** 2/26/2020	*3/5/2020	*3/30/2020	*4/16/2020	*5/5/2020	**5/19/2020	*5/28/2020
Depth to water	4.41	--	4.98	4.11	4.12	4.28	--	3.23	--	--	4.09	4.60	4.45	3.34	2.15	2.88	3.83	4.22
pH	7.42	12.62	12.77	12.40	11.92	12.67	--	8.03	--	--	12.77	--	12.99	13.52	13.21	--	12.97	--
Temperature °C	13.7	18.0	14.4	13.7	12.9	11.6	--	11.1	--	--	8.5	--	11.0	10.4	10.5	--	13.60	--
Dissolved Oxygen (mg/L)	0.90	--	--	--	--	--	--	--	--	--	--	--	7.08	11.78	--	--	--	--
Oxidation Reduction Potential (ORP)	-147.6	--	--	--	--	--	--	--	--	--	--	--	393.1	395.8	--	--	--	--
Klozur Persulfate (g/L)	--	21.0	23.5	20.5	20.3	20.5	--	5.1	--	--	44.0	--	35.0	35.0	24.75	--	27.75	--
Sulfate (mg/L)	24	375	--	--	--	--	--	--	--	--	2,470	--	--	--	--	--	--	--
Shallow Sock Weight (lbs)	NA	6 lbs 15 oz	6 lbs 6 oz	5 lbs 5 oz	4 lbs 8 oz	6 lbs 6 oz	3 lbs 13 oz		5 lbs 9 oz	--	8 lbs 11 oz	7 lbs 0 oz	6 lbs 7 oz	4 lbs 15 oz	5 lbs 4 oz	4 lbs 13 oz	4 lbs 11 oz	13 lbs 8 oz
Deep Sock Weight (lbs)	NA	8 lbs 14 oz	7 lbs	6 lbs 14 oz	Stuck on bottom	9 lbs 11 oz	4 lbs 9 oz		4 lbs	--	1 lb 8 oz	10 lbs 5 oz	10 lbs 10 oz	8lbs 7 oz	8 lbs 14 oz	8 lbs 7 oz	6 lbs 13 oz	13 lbs 12 oz
Shallow Sock Weight (kg)	NA	3.1	2.9	2.4	2.0	2.9	1.7	--	2.5	0.1	3.9	3.2	2.9	2.2	2.4	2.18	2.13	6.12
Deep Sock Weight (kg)	NA	4.0	3.2	3.1	--	4.4	2.1	--	1.8	0.6	0.7	4.7	4.8	3.8	4.0	3.8	3.1	6.2

Well ID	TW-4A																	
Date:	9/28/2019	10/7/2019	10/14/2019	10/28/2019	11/11/2019	11/25/2019	12/5/2019	1/9/2020	1/14/2020	2/4/2020	2/19/2020	2/26/2020	3/5/2020	3/30/2020	4/16/2020	5/5/2020	5/19/2020	5/28/2020
Depth to water	4.25	--	4.51	3.64	4.13	3.51	3.76	2.92	--	--	3.41	3.98	3.89	2.68	1.47	2.22	3.19	3.56
pH	6.95	12.36	12.48	12.50	12.52	--	12.40	12.30	--	--	13.00	--	12.93	13.54	13.13	--	12.93	--
Temperature °C	16.9	21.0	14.3	13.6	14.1	--	11.7	6.6	--	--	9.4	--	9.5	10.6	10.6	--	16.40	--
Dissolved Oxygen (mg/L)	0.19	--	--	--	--	--	--	--	--	--	--	--	26.00	28.45	--	--	--	--
Oxidation Reduction Potential (ORP)	-87.5	--	--	--	--	--	--	--	--	--	--	--	387.9	366.9	--	--	--	--
Klozur Persulfate (g/L)	--	25.0	23.5	20.5	17.0	--	5.5	3.5	--	--	47.0	--	29.0	22.0	16.0	--	19.00	--
Sulfate (mg/L)	8.70	425	--	--	--	--	--	--	--	--	2,230	--	--	--	--	--	--	--
Shallow Sock Weight (lbs)	NA	11 lbs 3 oz	8 lbs 5 oz	5 lbs 11 oz	3 lbs 11 oz	2 lbs 1 oz	1 lb 11 oz	1 lbs 6 oz	3 lbs 15 oz	0 lbs 9 oz			12 lbs 8 oz	8 lbs 10 oz	6 lbs 8 oz	3 lbs 15 oz	2 lbs 11 oz	12 lbs 12 oz
Deep Sock Weight (lbs)	NA	10 lbs 15 oz	8 lbs 8 oz	8 lbs 1 oz	5 lbs 10 oz	3 lbs 8 oz	4 lbs 2 oz	2 lbs 8 oz	5 lbs	1 lbs 7 oz	9 lbs 15 oz		9 lbs 8 oz	7 lbs 8 oz	6 lbs 5 oz	6 lbs 13 oz	5 lbs 15 oz	12 lbs 7 oz
Shallow Sock Weight (kg)	NA	5.1	3.8	2.6	1.7	0.9	0.8	0.6	1.8	0.3	--	5.6	5.7	3.9	2.9	1.79	1.22	5.78
Deep Sock Weight (kg)	NA	5.0	3.9	3.7	2.6	1.6	1.9	1.1	2.3	0.7	4.5	5.2	4.3	3.4	2.9	3.1	2.7	5.6

Well ID	TW-4B																
Date:	9/28/2019	10/7/2019	10/14/2019	10/28/2019	11/25/2019	12/5/2019	1/9/2020	1/14/2020	2/4/2020	2/19/2020	2/26/2020	3/5/2020	3/30/2020	4/16/2020	5/5/2020	5/19/2020	5/28/2020
Depth to water	5.25	--	5.43	4.53	4.34	4.46	3.56	--	--	4.05	4.56	4.49	3.30	2.17	2.98	3.88	4.27
pH	6.64	12.68	12.83	12.87	11.98	12.26	12.22	--	--	12.98	--	12.88	13.44	13.15	--	12.89	--
Temperature °C	14.6	18.5	14.4	13.5	12.8	10.8	7.6	--	--	9.6	--	10.3	10.9	10.6	--	15.3	--
Dissolved Oxygen (mg/L)	0.24	--	--	--	--	--	--	--	--	--	--	20.78	27.53	--	--	--	--
Oxidation Reduction Potential (ORP)	-109.6	--	--	--	--	--	--	--	--	--	--	401.2	384.0	--	--	--	--
Klozur Persulfate (g/L)	--	24.5	26.5	23.0	8.5	8.0	0.0	--	--	46.5	--	24.75	24.75	19.0	--	17.5	--
Sulfate (mg/L)	6.60	405	--	--	--	--	--	--	--	2,420	--	--	--	--	--	--	--
Shallow Sock Weight (lbs)	NA	9 lbs 4 oz	9 lbs 3 oz	5 lbs 6 oz	1 lb 7 oz	12 oz	1 lb 10 oz	2 lbs 8 oz	0 lbs 8 oz	--	7 lbs 1 oz	6 lbs 4 oz	5 lbs 9 oz	2 lbs 4 oz	6 lbs 13 oz	6 lbs 6 oz	9 lbs 15 oz
Deep Sock Weight (lbs)	NA	7 lbs 9 oz	4 lbs 10 oz	4 lbs 10 oz	5 lbs 0 oz	4 lbs 7 oz	2 lbs 3 oz	4 lbs 15 oz	1 lbs 0 oz	7 lbs 15 oz	10 lbs 14 oz	7 lbs 10 oz	4 lbs 8 oz	5 lbs 4 oz	3 lbs 13 oz	4 lbs 7 oz	10 lbs 15 oz
Shallow Sock Weight (kg)	NA	4.2	4.2	2.4	0.7	0.3	0.7	1.1	0.2	--	3.2	2.8	2.5	1.0	3.1	2.9	4.5
Deep Sock Weight (kg)	NA	3.4	2.1	2.1	2.3	2.0	1.0	2.2	0.5	3.6	5.0	3.5	2.0	2.4	1.7	2.0	5.0

Well ID	PZ-8I															
Date:	10/2/2019	*10/7/2019	*10/14/2019	*10/28/2019	*11/25/2019	*12/5/2019	*1/9/2020	*2/4/2020	*2/19/2020	*2/26/2019	*3/5/2020	*3/30/2020	*4/16/2020	*5/5/2020	**5/19/2020	*5/28/2020
Depth to water	5.11	--	5.60	4.49	1.82	3.91	3.20	4.70	3.54	3.95	4.90	2.75	1.63	2.38	3.37	3.77
pH	6.76	7.03	7.73	7.18	8.33	8.85	10.26	7.64	8.85	--	6.60	5.86	3.74	--	6.56	--
Temperature°C	17.8	18.1	15.1	16.1	12.5	10.1	5.3	8.6	8.3	--	9.9	10.4	10.2	--	14.3	--
Dissolved Oxygen (mg/L)	0.14	--	--	0.23	--	--	12.49	--	--	--	10.80	3.58	--	--	--	--
Oxidation Reduction Potential (ORP)	-97.6	--	--	-45.5	--	--	97.3	--	--	--	-17.0	16.4	--	--	--	--
Klozur Persulfate (g/L)	--	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--	0.0	0.0	0.0	--	0.0	--
Sulfate (mg/L)	22.0	36.5	19.3	13.3	< 5	11.1	108	260	375	--	1,260	285	--	--	--	--
TSS (mg/L)	--	--	--	--	--	--	--	--	--	--	--	16,300	--	--	--	--

Notes:

NA = Not applicable; -- = Not Measured; kg = Kilograms; g/L = grams per Liter
*Product detected; Product recovered and absorbents installed in wells.
** Well not monitored for product during event.

APPENDIX C
TREATABILITY STUDY ANALYTICAL DATA REPORTS

APPENDIX D
AQUIFER TESTING DATA

APPENDIX E
SOIL BORING AND WELL LOGS

Civil & Environmental Consultants, Inc.
31 Bellows Road
Raynham, MA 02767

BORING NUMBER STW-1A

Client: BASF

Project Name: BASF Cranston

Project Number: 172-818

Project Location: Cranston, RI

Date Started: 08/30/2019

Date Completed: 08/30/2019

CEC Field Representative: Dylan Lundgren

Log Checked By: Glen Cote

Ground Elevation:

Casing Elevation: NA

Latitude: 41.765921

Longitude: -71.411898

Drilling Contractor: Drillex

Driller: Tim Lafleck

Drilling Method: Direct Push

Core Size: NA

Backfill: with Bentonite

Borehole Diameter: 2.00 in

Well Installed: None

Stickup: None

Key: NA

Outer Casing: NA

Monitoring Equipment:

Development Method: NA

Results: NA

Yield: NA

Water Levels

At Drilling: NA

End of Drilling: NA

After Drilling: NA

Temporary Well: NA

Permanant Well : NA

Notes: Log Prepared by Dylan Lundgren

NA - Not Available; bgs - below ground surface; amsl - above mean sea level

BORING NUMBER STW-1A

Civil & Environmental Consultants, Inc.
31 Bellows Road
Raynham, MA 02767

CLIENT BASF

PROJECT NAME BASF Cranston

PROJECT NUMBER 172-818

PROJECT LOCATION Cranston, RI

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	RECOVERY % (RQD)	BLOWS COUNTS (N VALUES)	PID (PPM)	WELL DIAGRAM
0		Discrete Sampling (started collecting samples at 15'BSG)				
5						
10						
15.0		Black, GRAVEL, Little Fine Sand, Wet			0.9	
17.0		Gray, Fine Grained, SAND, and Silt, Wet	100	--	2.8	
					1.9	
20.0		Dark Gray and Black, Fine Grained, SAND, and Silt, Wet				
20.5		Gray, Fine Grained, SAND, and Silt, Wet			0.0	
			60	--		
25.0		Gray, Fine Grained, SAND, and Silt, Saturated			0.0	
			100	--	0.0	
					0.0	
30.0		End of boring at 30.0 feet				
35						

Civil & Environmental Consultants, Inc.
31 Bellows Road
Raynham, MA 02767

BORING NUMBER STW-1B

Client: BASF

Project Name: BASF Cranston

Project Number: 172-818

Project Location: Cranston, RI

Date Started: 08/30/2019

Date Completed: 08/30/2019

CEC Field Representative: Dylan Lundgren

Log Checked By: Glen Cote

Ground Elevation:

Casing Elevation: NA

Latitude: 41.765913

Longitude: -71.411921

Drilling Contractor: Drillex

Driller: Tim Lafleck

Drilling Method: Direct Push

Core Size: NA

Backfill: with Bentonite

Borehole Diameter: 2.00 in

Well Installed: None

Stickup: None

Key: NA

Outer Casing: NA

Monitoring Equipment:

Development Method: NA

Results: NA

Yield: NA

Water Levels

At Drilling: NA

End of Drilling: NA

After Drilling: NA

Temporary Well: NA

Permanant Well : NA

Notes: Log Prepared by Dylan Lundgren

NA - Not Available; bgs - below ground surface; amsl - above mean sea level

Civil & Environmental Consultants, Inc.
31 Bellows Road
Raynham, MA 02767

BORING NUMBER STW-1B

CLIENT BASF

PROJECT NAME BASF Cranston

PROJECT NUMBER 172-818

PROJECT LOCATION Cranston, RI

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	RECOVERY % (RQD)	BLOWS COUNTS (N VALUES)	PID (PPM)	WELL DIAGRAM
0		Discrete Sampling (started collecting samples at 15' BSG)				
5		▽				
10						
15	15.0	Black, GRAVEL, with Fine Sand, Wet			1.4	
	17.0	Gray, Fine Grained, SAND, and Silt, Wet	100	--	2.0	
					0.8	
20	20.0	Gray, Fine Grained, SAND, and Silt, Saturated			0.0	
			40	--		
25					0.1	
			100	--	0.0	
					0.0	
30	30.0	End of boring at 30.0 feet				
35						

Civil & Environmental Consultants, Inc.
31 Bellows Road
Raynham, MA 02767

BORING NUMBER STW-2A

Client: BASF

Project Name: BASF Cranston

Project Number: 172-818

Project Location: Cranston, RI

Date Started: 08/30/2019

Date Completed: 08/30/2019

CEC Field Representative: Dylan Lundgren

Log Checked By:

Ground Elevation:

Casing Elevation: NA

Latitude:

Longitude:

Drilling Contractor: Drillex

Driller: Tim Lafleck

Drilling Method: Direct Push

Core Size: NA

Backfill: with Bentonite

Borehole Diameter: 2.00 in

Well Installed: None

Stickup: None

Key: NA

Outer Casing: NA

Monitoring Equipment:

Development Method: NA

Results: NA

Yield: NA

Water Levels

At Drilling: NA

End of Drilling: NA

After Drilling: NA

Temporary Well: NA

Permanant Well : NA

Notes:

NA - Not Available; bgs - below ground surface; amsl - above mean sea level

Civil & Environmental Consultants, Inc.
31 Bellows Road
Raynham, MA 02767

BORING NUMBER STW-2A

CLIENT BASF

PROJECT NAME BASF Cranston

PROJECT NUMBER 172-818

PROJECT LOCATION Cranston, RI

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	RECOVERY % (RQD)	BLOWS COUNTS (N VALUES)	PID (PPM)	WELL DIAGRAM
0		Discrete Sampling (started collecting samples at 15' BSG)				
15.0		Black, GRAVEL, Some Fine Sand, Wet, Slight Sheen			26.9	
17.0		Gray, Fine Grained, SAND AND SILT, Wet	80	--	6.9	
20.0		End of boring at 20.0 feet				End of boring at 20.0 feet due to sheen
		End of boring at 20.0 feet due to sheen				

Depth scale: 0, 5, 10, 15, 20, 25, 30, 35

Civil & Environmental Consultants, Inc.
31 Bellows Road
Raynham, MA 02767

BORING NUMBER STW-2B

Client: BASF

Project Name: BASF Cranston

Project Number: 172-818

Project Location: Cranston, RI

Date Started: 08/30/2019

Date Completed: 08/30/2019

CEC Field Representative: Dylan Lundgren

Log Checked By:

Ground Elevation:

Casing Elevation: NA

Latitude:

Longitude:

Drilling Contractor: Drillex

Driller: Tim Lafleck

Drilling Method: Direct Push

Core Size: NA

Backfill: with Bentonite

Borehole Diameter: 2.00 in

Well Installed: None

Stickup: None

Key: NA

Outer Casing: NA

Monitoring Equipment:

Development Method: NA

Results: NA

Yield: NA

Water Levels

At Drilling: NA

Permanant Well : NA

End of Drilling: NA

After Drilling: NA

Temporary Well: NA

Notes:

NA - Not Available; bgs - below ground surface; amsl - above mean sea level

Civil & Environmental Consultants, Inc.
31 Bellows Road
Raynham, MA 02767

BORING NUMBER STW-2B

CLIENT BASF **PROJECT NAME** BASF Cranston

PROJECT NUMBER 172-818 **PROJECT LOCATION** Cranston, RI

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	RECOVERY % (RQD)	BLOWS COUNTS (N VALUES)	PID (PPM)	WELL DIAGRAM
0		Discrete Sampling (started collecting samples at 15' BSG)				
5						
10						
15	15.0	Black, GRAVEL, Some Fine Sand, Wet, (OUTWASH)			350.0	
	17.0	Gray, Fine Grained, SAND AND SILT, Wet, Heavy Sheen	92	--	105.0	
					30.0	
20	20.0	End of boring at 20.0 feet				End of boring at 20.0 feet due to sheen
25						
30						
35						

Civil & Environmental Consultants, Inc.
31 Bellows Road
Raynham, MA 02767

BORING NUMBER STW-3A

Client: BASF

Project Name: BASF Cranston

Project Number: 172-818

Project Location: Cranston, RI

Date Started: 09/03/2019

Date Completed: 09/03/2019

CEC Field Representative: Dylan Lundgren

Log Checked By:

Ground Elevation:

Casing Elevation: NA

Latitude:

Longitude:

Drilling Contractor: Drillex

Driller: Tim Lafleck

Drilling Method: Direct Push

Core Size: NA

Backfill: with Bentonite

Borehole Diameter: 2.00 in

Well Installed: None

Stickup: None

Key: NA

Outer Casing: NA

Monitoring Equipment:

Development Method: NA

Results: NA

Yield: NA

Water Levels

At Drilling: NA

End of Drilling: NA

After Drilling: NA

Temporary Well: NA

Permanant Well : NA

Notes:

NA - Not Available; bgs - below ground surface; amsl - above mean sea level

Civil & Environmental Consultants, Inc.
31 Bellows Road
Raynham, MA 02767

BORING NUMBER STW-3A

CLIENT BASF **PROJECT NAME** BASF Cranston

PROJECT NUMBER 172-818 **PROJECT LOCATION** Cranston, RI

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	RECOVERY % (RQD)	BLOWS COUNTS (N VALUES)	PID (PPM)	WELL DIAGRAM
0		Discrete Sampling (started collecting samples at 15' BSG)				
15.0		Black, Fine to Coarse Grained, GRAVEL, Little Fine Sand, Wet			6.9	
17.0		Gray, Fine Grained, SAND AND SILT, Trace Clay, Wet, Slight Sheen	92	--	23.6 12.1	
20.0		End of boring at 20.0 feet				End of boring at 20.0 feet due to sheen

Civil & Environmental Consultants, Inc.
31 Bellows Road
Raynham, MA 02767

BORING NUMBER STW-3B

Client: BASF

Project Name: BASF Cranston

Project Number: 172-818

Project Location: Cranston, RI

Date Started: 09/04/2019

Date Completed: 09/04/2019

CEC Field Representative: Dylan Lundgren

Log Checked By:

Ground Elevation:

Casing Elevation: NA

Latitude:

Longitude:

Drilling Contractor: Drillex

Driller: Tim Lafleck

Drilling Method: 4-1/4" Hollow Stem Auger + SPT

Core Size: NA

Backfill: with Bentonite

Borehole Diameter: 2.00 in

Well Installed: None

Stickup: None

Key: NA

Outer Casing: NA

Monitoring Equipment:

Development Method: NA

Results: NA

Yield: NA

Water Levels

At Drilling: NA

End of Drilling: NA

After Drilling: NA

Temporary Well: NA

Permanant Well : NA

Notes:

NA - Not Available; bgs - below ground surface; amsl - above mean sea level

Civil & Environmental Consultants, Inc.
31 Bellows Road
Raynham, MA 02767

BORING NUMBER STW-3B

CLIENT BASF

PROJECT NAME BASF Cranston

PROJECT NUMBER 172-818

PROJECT LOCATION Cranston, RI

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	RECOVERY % (RQD)	BLOWS COUNTS (N VALUES)	PID (PPM)	WELL DIAGRAM
0		Augered to 14' (started collecting samples at 14' BSG)				
5		▽				
14.0		Brown to Light Brown, Fine to Medium Grained, SAND, Dry				
15.0		Black, Fine to Coarse Grained, SAND, Wet, Slight Sheen	66	--	6.0	
17.0		Gray, Fine Grained, SAND AND SILT, Wet	50	--	118.0	
18.0		End of boring at 18.0 feet				End of boring at 18.0 feet due to sheen

Depth scale: 0, 5, 10, 15, 20, 25, 30, 35

Civil & Environmental Consultants, Inc.
31 Bellows Road
Raynham, MA 02767

BORING NUMBER STW-4A

Client: BASF

Project Name: BASF Cranston

Project Number: 172-818

Project Location: Cranston, RI

Date Started: 09/03/2019

Date Completed: 09/03/2019

CEC Field Representative: Dylan Lundgren

Log Checked By:

Ground Elevation:

Casing Elevation: NA

Latitude:

Longitude:

Drilling Contractor: Drillex

Driller: Tim Lafleck

Drilling Method: 4-1/4" Hollow Stem Auger + SPT

Core Size: NA

Backfill: with Bentonite

Borehole Diameter: 2.00 in

Well Installed: None

Stickup: None

Key: NA

Outer Casing: NA

Monitoring Equipment:

Development Method: NA

Results: NA

Yield: NA

Water Levels

At Drilling: NA

End of Drilling: NA

After Drilling: NA

Temporary Well: NA

Permanant Well : NA

Notes:

NA - Not Available; bgs - below ground surface; amsl - above mean sea level

Civil & Environmental Consultants, Inc.
31 Bellows Road
Raynham, MA 02767

BORING NUMBER STW-4A

CLIENT BASF

PROJECT NAME BASF Cranston

PROJECT NUMBER 172-818

PROJECT LOCATION Cranston, RI

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	RECOVERY % (RQD)	BLOWS COUNTS (N VALUES)	PID (PPM)	WELL DIAGRAM
0		Augered to 13 (started collecting samples at 13' BSG)				
5		▽				
10						
13.0	▨	Brown, Fine to Coarse Grained, SAND, Trace Silt, Trace Gravel, Wet	6	13-4-3-2 (7)	1.2	
15.0	▨	Black, Fine to Coarse Grained, GRAVEL, with Fine Sand, Wet	50	2-1-8-6 (9)	23.7	
17.0		End of boring at 17.0 feet				
20						
25						
30						
35						

Civil & Environmental Consultants, Inc.
31 Bellows Road
Raynham, MA 02767

BORING NUMBER STW-4B

Client: BASF

Project Name: BASF Cranston

Project Number: 172-818

Project Location: Cranston, RI

Date Started: 09/03/2019

Date Completed: 09/03/2019

CEC Field Representative: Dylan Lundgren

Log Checked By:

Ground Elevation:

Casing Elevation: NA

Latitude:

Longitude:

Drilling Contractor: Drillex

Driller: Tim Lafleck

Drilling Method: Direct Push

Core Size: NA

Backfill: with Bentonite

Borehole Diameter: 2.00 in

Well Installed: None

Stickup: None

Key: NA

Outer Casing: NA

Monitoring Equipment:

Development Method: NA

Results: NA

Yield: NA

Water Levels

At Drilling: NA

End of Drilling: NA

After Drilling: NA

Temporary Well: NA

Permanant Well : NA

Notes:

NA - Not Available; bgs - below ground surface; amsl - above mean sea level

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BORING NUMBER STW-4B

CLIENT BASF
PROJECT NAME BASF Cranston
PROJECT NUMBER 172-818
PROJECT LOCATION Cranston, RI

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	RECOVERY % (RQD)	BLOWS COUNTS (N VALUES)	PID (PPM)	WELL DIAGRAM
0		Discrete Sampling (started collecting samples at 15' BSG)				
15.0		Black, Fine to Coarse Grained, GRAVEL, Little Fine to Coarse Sand, Wet			14.2	
17.0		Gray, Fine Grained, SAND AND SILT, Trace Clay, Wet	90	--	70.9	
					39.5	
20.0		Gray, CLAY, Little Silt, Wet	33	--	1.4	
25.0		End of boring at 25.0 feet				

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BORING NUMBER STW-5A

Client: BASF

Project Name: BASF Cranston

Project Number: 172-818

Project Location: Cranston, RI

Date Started: 09/03/2019

Date Completed: 09/03/2019

CEC Field Representative: Dylan Lundgren

Log Checked By:

Ground Elevation:

Casing Elevation: NA

Latitude:

Longitude:

Drilling Contractor: Drillex

Driller: Tim Lafleck

Drilling Method: 4-1/4" Hollow Stem Auger + SPT

Core Size: NA

Backfill: with Bentonite / Cement Cap

Borehole Diameter: 2.00 in

Well Installed: None

Stickup: None

Key: NA

Outer Casing: NA

Monitoring Equipment:

Development Method: NA

Results: NA

Yield: NA

Water Levels

At Drilling: NA

End of Drilling: NA

After Drilling: NA

Temporary Well: NA

Permanant Well : NA

Notes:

NA - Not Available; bgs - below ground surface; amsl - above mean sea level

Civil & Environmental Consultants, Inc.
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BORING NUMBER STW-5A

CLIENT BASF

PROJECT NAME BASF Cranston

PROJECT NUMBER 172-818

PROJECT LOCATION Cranston, RI

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	RECOVERY % (RQD)	BLOWS COUNTS (N VALUES)	PID (PPM)	WELL DIAGRAM
0		Augered to 10' (started collecting samples at 10' BSG)				
5		▽				
10	10.0	Brown Black, GRAVEL, with Fine Sand, and Silt, Trace Organics, Wet, Very Loose	8	WOH-WOH-1-2 (1)		
	12.0	Black, SAND AND GRAVEL, Trace Organics, Wet, Loose	29	2-3-4-2 (7)	19.8	
15			50	WOH-WOH-2-5 (2)	50.3	
	17.0	Gray, Fine Grained, SAND AND SILT, Wet	83	4-6-14-16 (20)	80.6	
	18.0	End of boring at 18.0 feet				
20						
25						
30						
35						

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BORING NUMBER STW-5B

Client: BASF

Project Name: BASF Cranston

Project Number: 172-818

Project Location: Cranston, RI

Date Started: 09/03/2019

Date Completed: 09/03/2019

CEC Field Representative: Dylan Lundgren

Log Checked By:

Ground Elevation:

Casing Elevation: NA

Latitude:

Longitude:

Drilling Contractor: Drillex

Driller: Tim Lafleck

Drilling Method: 4-1/4" Hollow Stem Auger + SPT

Core Size: NA

Backfill: with Bentonite / Cement Cap

Borehole Diameter: 2.00 in

Well Installed: None

Stickup: None

Key: NA

Outer Casing: NA

Monitoring Equipment:

Development Method: NA

Results: NA

Yield: NA

Water Levels

At Drilling: NA

End of Drilling: NA

After Drilling: NA

Temporary Well: NA

Permanant Well : NA

Notes:

NA - Not Available; bgs - below ground surface; amsl - above mean sea level

Civil & Environmental Consultants, Inc.
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BORING NUMBER STW-5B

CLIENT BASF | **PROJECT NAME** BASF Cranston

PROJECT NUMBER 172-818 | **PROJECT LOCATION** Cranston, RI

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	RECOVERY % (RQD)	BLOWS COUNTS (N VALUES)	PID (PPM)	WELL DIAGRAM
0		Augered to 14' (started collecting samples at 14' BSG)				
5		▽				
14.0		Black, Coarse Grained, SAND, Trace Organics, Wet, Slight Sheen	21	2-2-2-7 (4)	151.0	
16.5		Gray, Fine Grained, SAND AND SILT, Wet, Slight Sheen	66	7-10-13-17 (23)	200.0	
18.0		End of boring at 18.0 feet				

Depth scale: 0, 5, 10, 15, 20, 25, 30, 35

Civil & Environmental Consultants, Inc.
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BORING NUMBER STW-6A

Client: BASF

Project Name: BASF Cranston

Project Number: 172-818

Project Location: Cranston, RI

Date Started: 09/30/2019

Date Completed: 09/03/2019

CEC Field Representative: Dylan Lundgren

Log Checked By:

Ground Elevation:

Casing Elevation: NA

Latitude:

Longitude:

Drilling Contractor: Drillex

Driller: Tim Lafleck

Drilling Method: 4-1/4" Hollow Stem Auger + SPT

Core Size: NA

Backfill: with Bentonite / Concrete Cap

Borehole Diameter: 2.00 in

Well Installed: None

Stickup: None

Key: NA

Outer Casing: NA

Monitoring Equipment:

Development Method: NA

Results: NA

Yield: NA

Water Levels

At Drilling: NA

End of Drilling: NA

After Drilling: NA

Temporary Well: NA

Permanant Well : NA

Notes:

NA - Not Available; bgs - below ground surface; amsl - above mean sea level

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BORING NUMBER STW-6A

CLIENT BASF

PROJECT NAME BASF Cranston

PROJECT NUMBER 172-818

PROJECT LOCATION Cranston, RI

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	RECOVERY % (RQD)	BLOWS COUNTS (N VALUES)	PID (PPM)	WELL DIAGRAM
0		Augered to 14' (started collecting samples at 14' BSG)				
14.0		Black, Coarse Grained, SAND, Wet, Loose	92	2-5-4-5 (9)	10.4	
15.5		Gray, Fine Grained, SAND, Heavy Sheen				
16.0		Black, Coarse Grained, SAND, Wet				
16.5		Gray, Fine Grained, SAND AND SILT, Wet, Heavy Sheen	83	4-7-7-7 (14)	48.5	
18.0		End of boring at 18.0 feet				

Depth scale: 0, 5, 10, 15, 20, 25, 30, 35

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BORING NUMBER STW-6B

Client: BASF

Project Name: BASF Cranston

Project Number: 172-818

Project Location: Cranston, RI

Date Started: 09/04/2019

Date Completed: 09/04/2019

CEC Field Representative: Dylan Lundgren

Log Checked By:

Ground Elevation:

Casing Elevation: NA

Latitude:

Longitude:

Drilling Contractor: Drilex Environmental

Driller: Tim Lafleck

Drilling Method: 4-1/4-in Hollow Stem Auger + SPT

Core Size: NA

Backfill: with Bentonite / Concrete Cap

Borehole Diameter: 2.00 in

Well Installed: None

Stickup:

Key: NA

Outer Casing: NA

Monitoring Equipment:

Development Method: NA

Results: NA

Yield: NA

Water Levels

At Drilling: NA

End of Drilling: NA

After Drilling: NA

Temporary Well: NA

Permanant Well : NA

Notes:

NA - Not Available; bgs - below ground surface; amsl - above mean sea level

Civil & Environmental Consultants, Inc.
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BORING NUMBER STW-6B

CLIENT BASF

PROJECT NAME BASF Cranston

PROJECT NUMBER 172-818

PROJECT LOCATION Cranston, RI

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	RECOVERY % (RQD)	BLOWS COUNTS (N VALUES)	PID (PPM)	WELL DIAGRAM
0		Augered to 14' (started collecting samples at 14' BSG)				
5		▽				
10						
14.0 ft		Black, Fine to Medium Grained, SAND, Wet, Heavy Sheen	100	2-3-8-10 (11)	66.3	
16.5 ft		Gray, Fine Grained, SAND AND SILT, Wet, Sheen	83	9-9-9-15 (18)	12.3	
18.0 ft		End of boring at 18.0 feet				
20						
25						
30						
35						

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BORING NUMBER STW-7A

Client: BASF

Project Name: BASF Cranston

Project Number: 172-818

Project Location: Cranston, RI

Date Started: 09/04/2019

Date Completed: 09/04/2019

CEC Field Representative: Dylan Lundgren

Log Checked By:

Ground Elevation:

Casing Elevation: NA

Latitude:

Longitude:

Drilling Contractor: Drilex Environmental

Driller: Tim Lafleck

Drilling Method: 4-1/4-in Hollow Stem Auger + SPT

Core Size: NA

Backfill: with Bentonite / Concrete Cap

Borehole Diameter: 2.00 in

Well Installed: None

Stickup:

Key: NA

Outer Casing: NA

Monitoring Equipment:

Development Method: NA

Results: NA

Yield: NA

Water Levels

At Drilling: NA

End of Drilling: NA

After Drilling: NA

Temporary Well: NA

Permanant Well : NA

Notes:

NA - Not Available; bgs - below ground surface; amsl - above mean sea level

Civil & Environmental Consultants, Inc.
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BORING NUMBER STW-7A

CLIENT BASF

PROJECT NAME BASF Cranston

PROJECT NUMBER 172-818

PROJECT LOCATION Cranston, RI

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	RECOVERY % (RQD)	BLOWS COUNTS (N VALUES)	PID (PPM)	WELL DIAGRAM
0		Augered to 14' (started collecting samples at 14' BSG)				
5		▽				
10						
14.0 ft		Brown Gray, Fine to Coarse Grained, SAND, Wet	21	3-2-1-2 (3)		
15						
16.5 ft		Gray, Fine Grained, SAND AND SILT, Wet	42	3-4-4-4 (8)	132.4	
18.0 ft		End of boring at 18.0 feet				
20						
25						
30						
35						

Civil & Environmental Consultants, Inc.
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BORING NUMBER STW-7B

Client: BASF

Project Name: BASF Cranston

Project Number: 172-818

Project Location: Cranston, RI

Date Started: 09/04/2019

Date Completed: 09/04/2019

CEC Field Representative: Dylan Lundgren

Log Checked By:

Ground Elevation:

Casing Elevation: NA

Latitude:

Longitude:

Drilling Contractor: Drilex Environmental

Driller: Tim Lafleck

Drilling Method: 4-1/4-in Hollow Stem Auger + SPT

Core Size: NA

Backfill: with Bentonite / Concrete Cap

Borehole Diameter: 2.00 in

Well Installed: None

Stickup:

Key: NA

Outer Casing: NA

Monitoring Equipment:

Development Method: NA

Results: NA

Yield: NA

Water Levels

At Drilling: NA

End of Drilling: NA

After Drilling: NA

Temporary Well: NA

Permanant Well : NA

Notes:

NA - Not Available; bgs - below ground surface; amsl - above mean sea level

Civil & Environmental Consultants, Inc.
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BORING NUMBER STW-7B

CLIENT BASF

PROJECT NAME BASF Cranston

PROJECT NUMBER 172-818

PROJECT LOCATION Cranston, RI

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	RECOVERY % (RQD)	BLOWS COUNTS (N VALUES)	PID (PPM)	WELL DIAGRAM
0		Augered to 14' (started collecting samples at 14' BSG)				
14.0 ft		Gray Brown, Fine Grained, SAND AND SILT, Wet				
15.0 ft		Black, SAND, Wet, Heavy Sheen	50	11-5-3-3 (8)	42.0	
17.0 ft		Gray, Fine Grained, SAND AND SILT, Wet, Heavy Sheen	62	3-6-6-7 (12)	2.2	
18.0 ft		End of boring at 18.0 feet				

Depth scale: 0, 5, 10, 15, 20, 25, 30, 35

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BORING NUMBER STW-8A

Client: BASF

Project Name: BASF Cranston

Project Number: 172-818

Project Location: Cranston, RI

Date Started: 09/04/2019

Date Completed: 09/04/2019

CEC Field Representative: Dylan Lundgren

Log Checked By:

Ground Elevation:

Casing Elevation: NA

Latitude:

Longitude:

Drilling Contractor: Drilex Environmental

Driller: Tim Lafleck

Drilling Method: 4-1/4-in Hollow Stem Auger + SPT

Core Size: NA

Backfill: with Bentonite / Concrete Cap

Borehole Diameter: 2.00 in

Well Installed: None

Stickup:

Key: NA

Outer Casing: NA

Monitoring Equipment:

Development Method: NA

Results: NA

Yield: NA

Water Levels

At Drilling: NA

End of Drilling: NA

After Drilling: NA

Temporary Well: NA

Permanant Well : NA

Notes:

NA - Not Available; bgs - below ground surface; amsl - above mean sea level

Civil & Environmental Consultants, Inc.
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BORING NUMBER STW-8A

CLIENT BASF

PROJECT NAME BASF Cranston

PROJECT NUMBER 172-818

PROJECT LOCATION Cranston, RI

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	RECOVERY % (RQD)	BLOWS COUNTS (N VALUES)	PID (PPM)	WELL DIAGRAM
0		Augered to 14' (started collecting samples at 14' BSG)				
5		▽				
10						
14.0 ft		Black, Fine to Medium Grained, SAND AND GRAVEL, Wet				
15			50	5-2-4-11 (6)	21.1	
17.0 ft		Gray, Fine Grained, SAND AND SILT, Some Medium to Coarse Gravel, Wet	50	3-4-5-11 (9)	25.5	
18.0 ft		End of boring at 18.0 feet				
20						
25						
30						
35						

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BORING NUMBER STW-8B

Client: BASF

Project Name: BASF Cranston

Project Number: 172-818

Project Location: Cranston, RI

Date Started: 09/04/2019

Date Completed: 09/04/2019

CEC Field Representative: Dylan Lundgren

Log Checked By:

Ground Elevation:

Casing Elevation: NA

Latitude:

Longitude:

Drilling Contractor: Drilex Environmental

Driller: Tim Lafleck

Drilling Method: 4-1/4-in Hollow Stem Auger + SPT

Core Size: NA

Backfill: with Bentonite / Concrete Cap

Borehole Diameter: 2.00 in

Well Installed: None

Stickup:

Key: NA

Outer Casing: NA

Monitoring Equipment:

Development Method: NA

Results: NA

Yield: NA

Water Levels

At Drilling: NA

End of Drilling: NA

After Drilling: NA

Temporary Well: NA

Permanant Well : NA

Notes:

NA - Not Available; bgs - below ground surface; amsl - above mean sea level

Civil & Environmental Consultants, Inc.
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BORING NUMBER STW-8B

CLIENT BASF

PROJECT NAME BASF Cranston

PROJECT NUMBER 172-818

PROJECT LOCATION Cranston, RI

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	RECOVERY % (RQD)	BLOWS COUNTS (N VALUES)	PID (PPM)	WELL DIAGRAM
0		Augered to 14' (started collecting samples at 14' BSG)				
5		▽				
14.0 ft		Brown, Fine Grained, SAND, Some Gravel, Moist	25	10-5-4-6 (9)	1.2	
17.0 ft		Gray, Fine Grained, SAND AND SILT, Wet, Sheen	75	4-4-5-8 (9)	54.8	
18.0 ft		End of boring at 18.0 feet				

Depth scale: 0, 5, 10, 15, 20, 25, 30, 35

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BORING NUMBER SPZ-8I

Client: BASF

Project Name: BASF Cranston

Project Number: 172-818

Project Location: Cranston, RI

Date Started: 08/30/2019

Date Completed: 08/30/2019

CEC Field Representative: Dylan Lundgren

Log Checked By:

Ground Elevation:

Casing Elevation: NA

Latitude:

Longitude:

Drilling Contractor: Drillex

Driller: Tim Lafleck

Drilling Method: Direct Push

Core Size: NA

Backfill: with Bentonite

Borehole Diameter: 2.00 in

Well Installed: None

Stickup: None

Key: NA

Outer Casing: NA

Monitoring Equipment:

Development Method: NA

Results: NA

Yield: NA

Water Levels

At Drilling: NA

End of Drilling: NA

After Drilling: NA

Temporary Well: NA

Permanant Well : NA

Notes:

NA - Not Available; bgs - below ground surface; amsl - above mean sea level

Civil & Environmental Consultants, Inc.
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BORING NUMBER SPZ-8I

CLIENT BASF

PROJECT NAME BASF Cranston

PROJECT NUMBER 172-818

PROJECT LOCATION Cranston, RI

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	RECOVERY % (RQD)	BLOWS COUNTS (N VALUES)	PID (PPM)	WELL DIAGRAM
0		Discrete Sampling (started collecting samples at 15' BSG)				
15.0		Black, GRAVEL, Little Fine Sand, Wet			21.2	
17.0		Gray, Fine Grained, SAND AND SILT, Wet, Heavy Sheen	87	--	9.6	
					0.3	
20.0		End of boring at 20.0 feet				End of boring at 20.0 feet due to sheen

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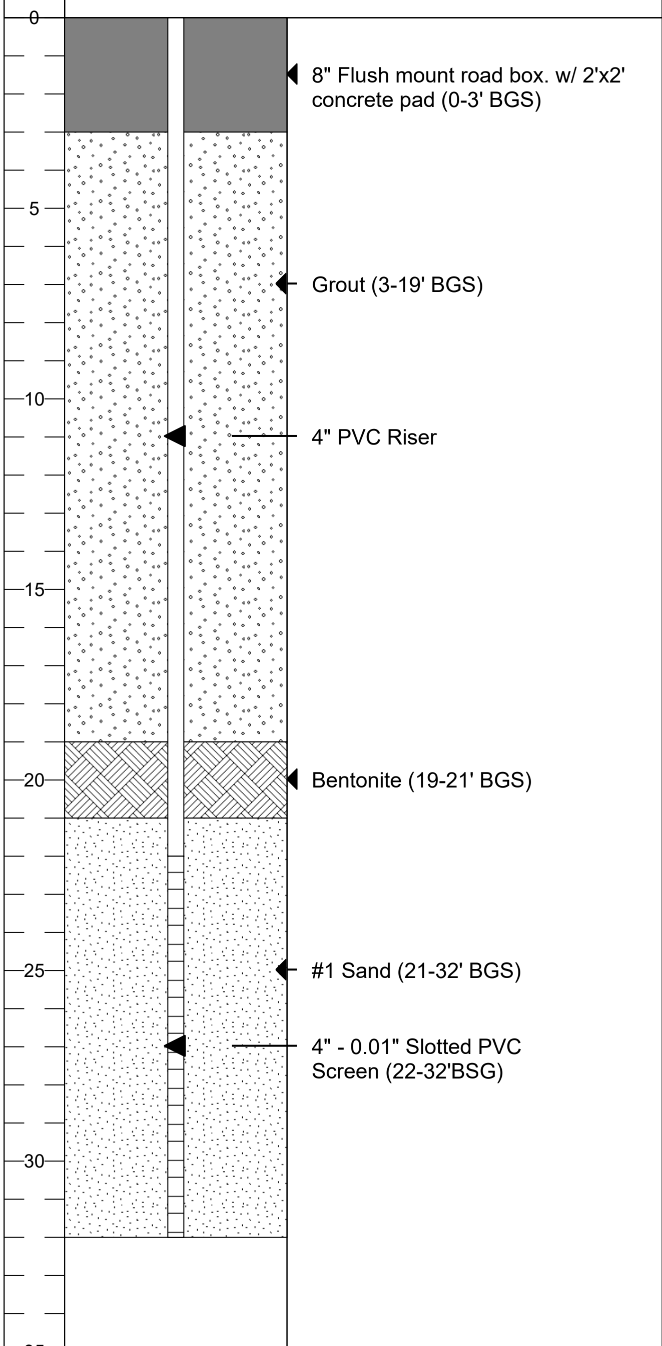
MONITORING WELL TW-1A

CLIENT BASF
PROJECT NAME BASF Cranston
PROJECT NUMBER 172-818
PROJECT LOCATION Cranston, RI
DATE STARTED 09/24/2019 **DATE COMPLETED** 09/24/2019
GROUND ELEVATION 12 ft **BACKFILL**
SAMPLING CONTRACTOR Geosearch, Inc.
LATITUDE 41.765910 **LONGITUDE** -71.411907
SAMPLING METHOD 6-1/4” Hollow Stem Auger
WATER LEVELS
AT END OF SOIL SAMPLING
CEC REP Glen Cote **CHECKED BY** Glen Cote
AT END OF CORING
NOTES
24 HRS AFTER DRILLING 09/28/2019 5.2 ft / Elev 6.4 ft

DEPTH (ft)	WELL DIAGRAM	MATERIAL DESCRIPTION	ELEVATION (ft)



(See STW Boring Logs)

32.0 -20.4

End of boring at 32.0 feet

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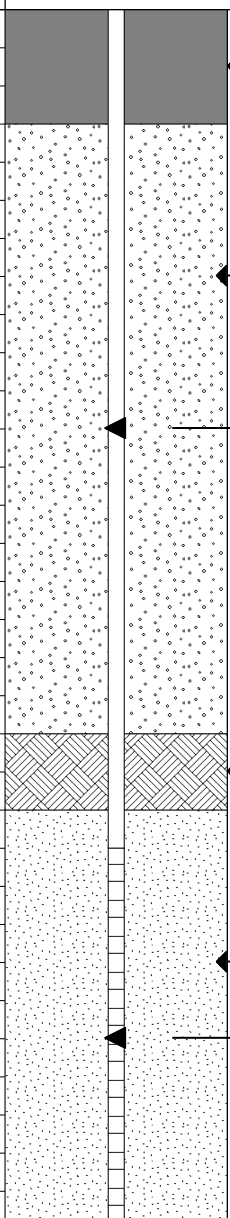
MONITORING WELL TW-1B

CLIENT	BASF	**PROJECT NAME**	BASF Cranston
PROJECT NUMBER	172-818	**PROJECT LOCATION**	Cranston, RI
DATE STARTED	09/24/2019	**DATE COMPLETED**	09/24/2019
GROUND ELEVATION	11 ft	**BACKFILL**	
SAMPLING CONTRACTOR	Geosearch, Inc.	**LATITUDE**	41.765928
LONGITUDE	-71.411932		
SAMPLING METHOD	6-1/4” Hollow Stem Auger		
CEC REP	Dylan Lundgren	**CHECKED BY**	Glen Cote
NOTES			

WATER LEVELS

AT END OF SOIL SAMPLING	
AT END OF CORING	
24 HRS AFTER DRILLING	09/28/2019 4.7 ft / Elev 6.5 ft

DEPTH (ft)	WELL DIAGRAM	MATERIAL DESCRIPTION	ELEVATION (ft)
0	8" Flush mount road box. w/ 2'x2' concrete pad (0-3' BGS)	(See STW Boring Logs)	
5			
	Grout (3-19' BGS)		
10			2
	4" PVC Riser		
15			
			-8
20	Bentonite (19-21' BGS)		
25	#1 Sand (21-32' BGS)		
	4" - 0.01" Slotted PVC Screen (22-32'BSG)		
			-18
30			
32.0		End of boring at 32.0 feet	-20.8
35			



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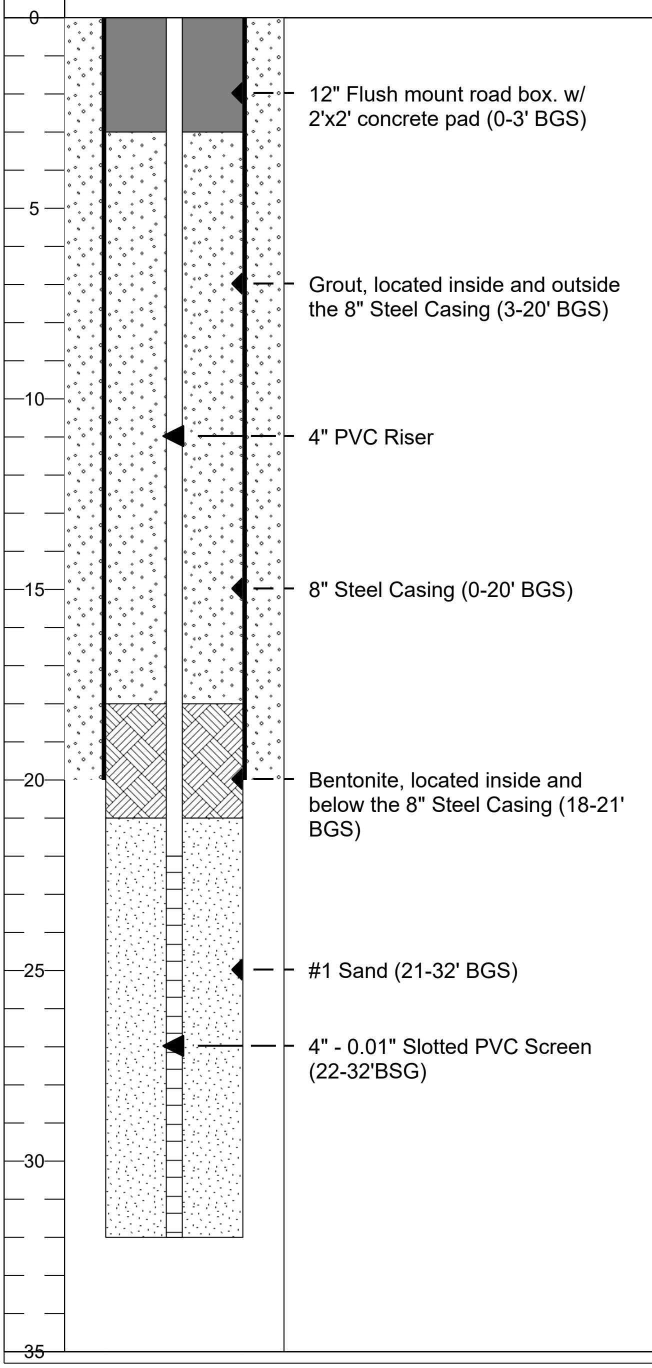
MONITORING WELL TW-2A

CLIENT BASF
PROJECT NAME BASF Cranston
PROJECT NUMBER 172-818
PROJECT LOCATION Cranston, RI
DATE STARTED 09/30/2019 **DATE COMPLETED** 09/30/2019
GROUND ELEVATION 11 ft **BACKFILL**
SAMPLING CONTRACTOR Geosearch, Inc.
LATITUDE 41.765926 **LONGITUDE** -71.411901
SAMPLING METHOD 10-1/4" + 6-1/4" HSA
WATER LEVELS
- **AT END OF SOIL SAMPLING**
- **AT END OF CORING**
- **24 HRS AFTER DRILLING** 09/30/2019 4.2 ft / Elev 6.7 ft

CEC REP Lauren Baldwin **CHECKED BY** Glen Cote
NOTES Double Cased Well

DEPTH (ft)	WELL DIAGRAM	MATERIAL DESCRIPTION	ELEVATION (ft)



(See STW Boring Logs)

Elevation scale: 1, -9, -19

32.0 -21.1

End of boring at 32.0 feet

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MONITORING WELL TW-2B

CLIENT BASF

PROJECT NAME BASF Cranston

PROJECT NUMBER 172-818

PROJECT LOCATION Cranston, RI

DATE STARTED 09/30/2019 **DATE COMPLETED** 09/30/2019

GROUND ELEVATION 12 ft **BACKFILL**

SAMPLING CONTRACTOR Geosearch, Inc.

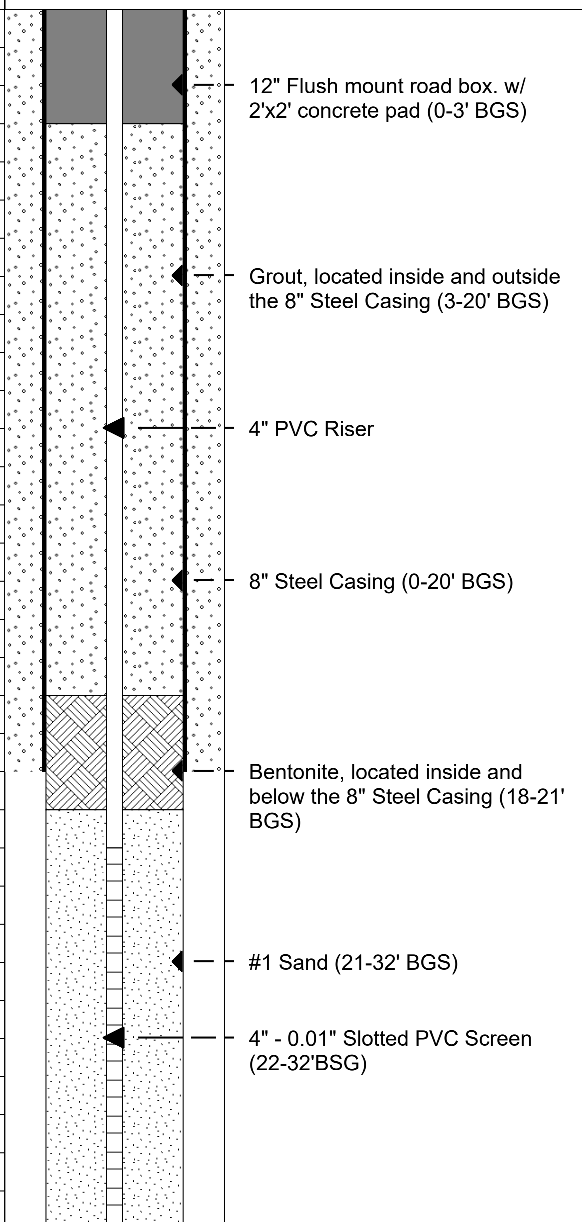
LATITUDE 41.765942 **LONGITUDE** -71.411919

SAMPLING METHOD 10-1/4" + 6-1/4" HSA

CEC REP Lauren Baldwin **CHECKED BY** Glen Cote

WATER LEVELS
- AT END OF SOIL SAMPLING
- AT END OF CORING
- 24 HRS AFTER DRILLING 09/30/2019 5.6 ft / Elev 6.1 ft

NOTES Double Cased Well

DEPTH (ft)	WELL DIAGRAM	MATERIAL DESCRIPTION	ELEVATION (ft)
0		(See STW Boring Logs)	
5			
10			2
15			
20			-8
25			
30			-18
32.0		End of boring at 32.0 feet	-20.3
35			

Civil & Environmental Consultants, Inc.
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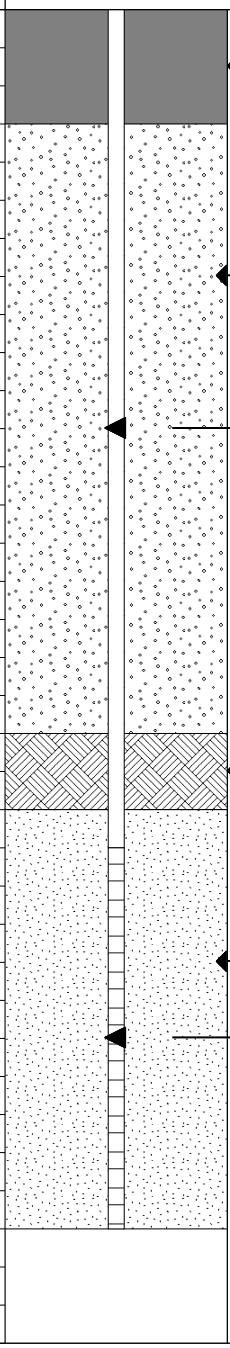
MONITORING WELL TW-3A

CLIENT	BASF	**PROJECT NAME**	BASF Cranston
PROJECT NUMBER	172-818	**PROJECT LOCATION**	Cranston, RI
DATE STARTED	09/25/2019	**DATE COMPLETED**	09/25/2019
GROUND ELEVATION	12 ft	**BACKFILL**	
SAMPLING CONTRACTOR	Geosearch, Inc.	**LATITUDE**	41.765941
LONGITUDE	-71.411893	**SAMPLING METHOD**	6-1/4” Hollow Stem Auger
CEC REP	Dylan Lundgren	**CHECKED BY**	Glen Cote
NOTES			

WATER LEVELS
- **AT END OF SOIL SAMPLING**
- **AT END OF CORING**
- **24 HRS AFTER DRILLING** 09/28/2019 5.5 ft / Elev 6.3 ft

DEPTH (ft)	WELL DIAGRAM	MATERIAL DESCRIPTION	ELEVATION (ft)
0		(See STW Boring Logs)	
5			
10			2
15			
20			-8
25			
30			-18
32.0		End of boring at 32.0 feet	-20.2
35			



8" Flush mount road box. w/ 2'x2' concrete pad (0-3' BGS)

Grout (3-19' BGS)

4" PVC Riser

Bentonite (19-21' BGS)

#1 Sand (21-32' BGS)

4" - 0.01" Slotted PVC Screen (22-32'BSG)

Civil & Environmental Consultants, Inc.
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Raynham, MA 02767

MONITORING WELL TW-3B

CLIENT BASF

PROJECT NAME BASF Cranston

PROJECT NUMBER 172-818

PROJECT LOCATION Cranston, RI

DATE STARTED 09/30/2019 **DATE COMPLETED** 09/30/2019

GROUND ELEVATION 11 ft **BACKFILL**

SAMPLING CONTRACTOR Geosearch, Inc.

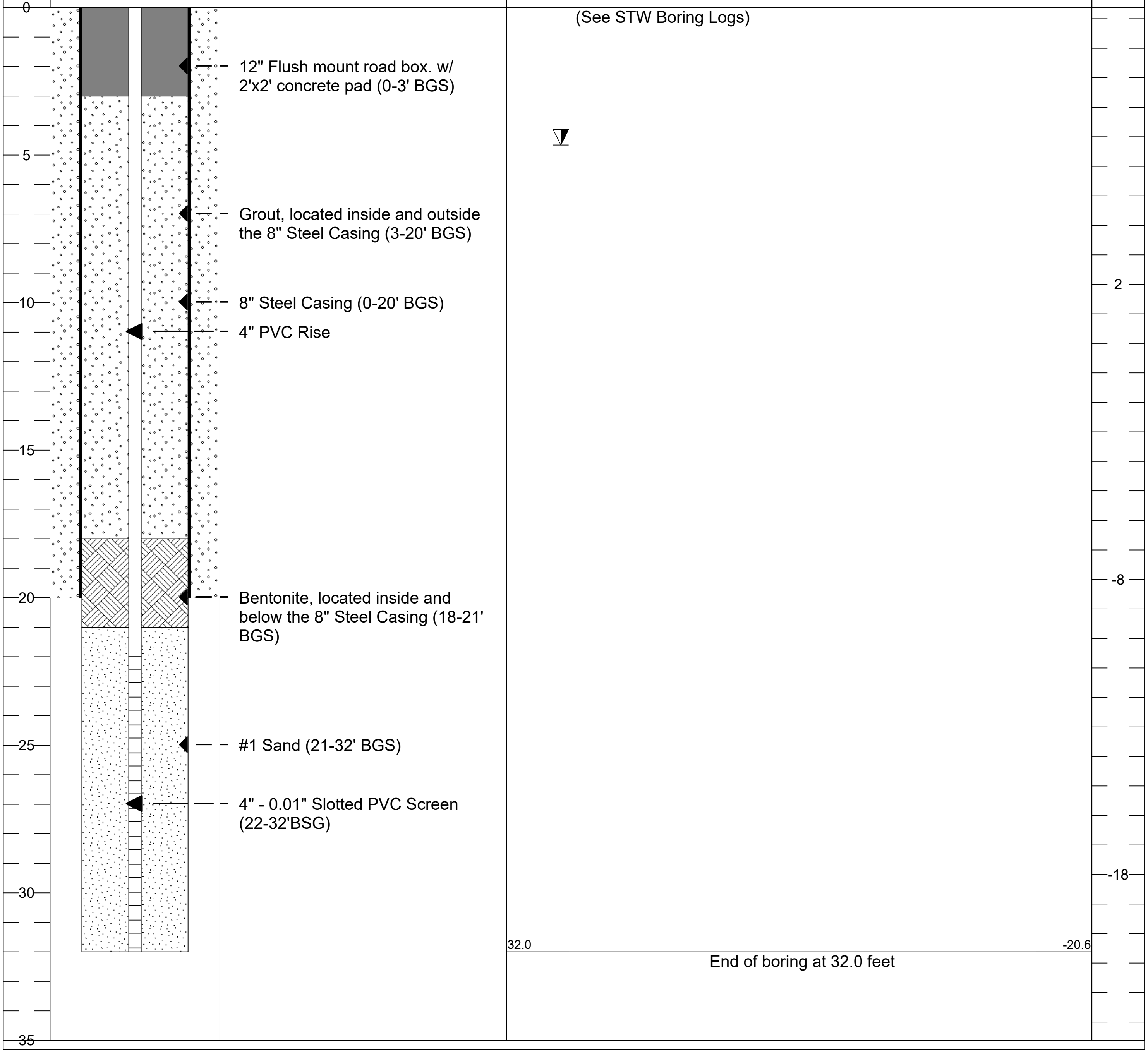
LATITUDE 41.765956 **LONGITUDE** -71.411908

SAMPLING METHOD 10-1/4" + 6-1/4" HSA

CEC REP Dylan Lundgren **CHECKED BY** Glen Cote

NOTES Double Cased Well

WATER LEVELS
- **AT END OF SOIL SAMPLING**
- **AT END OF CORING**
- **24 HRS AFTER DRILLING** 09/30/2019 4.4 ft / Elev 7.0 ft

DEPTH (ft)	WELL DIAGRAM	MATERIAL DESCRIPTION	ELEVATION (ft)
0–32.0		(See STW Boring Logs)	
32.0		End of boring at 32.0 feet	-20.6

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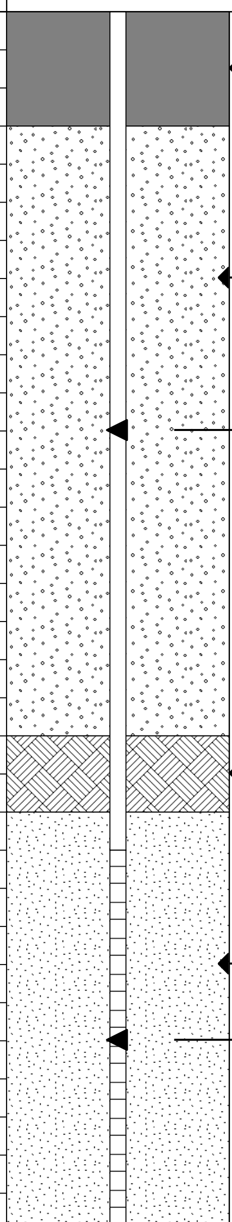
MONITORING WELL TW-4A

CLIENT	BASF	**PROJECT NAME**	BASF Cranston
PROJECT NUMBER	172-818	**PROJECT LOCATION**	Cranston, RI
DATE STARTED	09/25/2019	**GROUND ELEVATION**	11 ft
DATE COMPLETED	09/25/2019	**BACKFILL**	
SAMPLING CONTRACTOR	Geosearch, Inc.	**LATITUDE**	41.765952
SAMPLING METHOD	6-1/4” Hollow Stem Auger	**LONGITUDE**	-71.411876
CEC REP	Dylan Lundgren	**WATER LEVELS** AT END OF SOIL SAMPLING	
CHECKED BY	Glen Cote	**WATER LEVELS** AT END OF CORING	
NOTES		**WATER LEVELS** 24 HRS AFTER DRILLING	09/28/2019 4.5 ft / Elev 6.6 ft

DEPTH (ft)	WELL DIAGRAM	MATERIAL DESCRIPTION	ELEVATION (ft)
0		(See STW Boring Logs)	
5			
10			2
15			
20			-8
25			
30			-18
32.0		End of boring at 32.0 feet	-20.9
35			



8" Flush mount road box. w/ 2'x2' concrete pad (0-3' BGS)

Grout (3-19' BGS)

4" PVC Riser

Bentonite (19-21)

#1 Sand (21-32' BGS)

4" - 0.01" Slotted PVC Screen (22-32'BSG)

Civil & Environmental Consultants, Inc.
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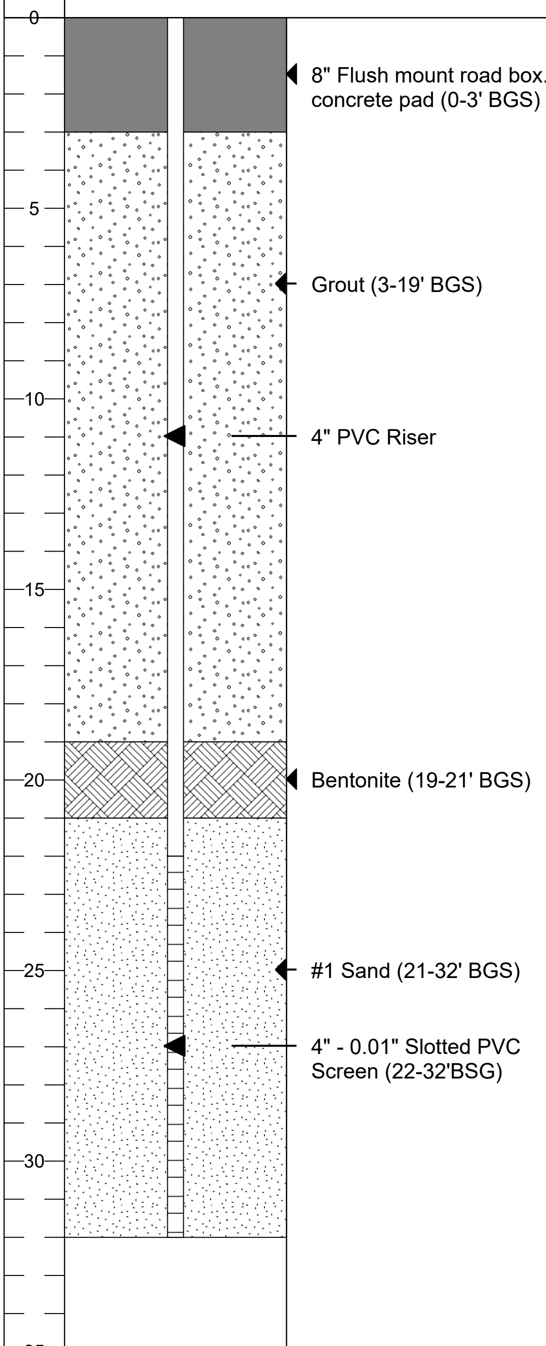
Raynham, MA 02767

MONITORING WELLTW-4B

CLIENT BASF
PROJECT NAME BASF Cranston
PROJECT NUMBER 172-818
PROJECT LOCATION Cranston, RI
DATE STARTED 09/25/2019 **DATE COMPLETED** 09/25/2019
GROUND ELEVATION 12 ft **BACKFILL**
SAMPLING CONTRACTOR Geosearch, Inc.
LATITUDE 41.766403 **LONGITUDE** -71.411894
SAMPLING METHOD 6-1/4” Hollow Stem Auger
WATER LEVELS
AT END OF SOIL SAMPLING
AT END OF CORING
24 HRS AFTER DRILLING 09/28/2019 5.3 ft / Elev 6.6 ft
CEC REP Dylan Lundgren **CHECKED BY** Glen Cote
NOTES

DEPTH (ft)	WELL DIAGRAM	MATERIAL DESCRIPTION	ELEVATION (ft)
0		(See STW Boring Logs)	
32.0		End of boring at 32.0 feet	-20.1



Elevation scale: 2, -8, -18

MONITORING WELL PZ-8I

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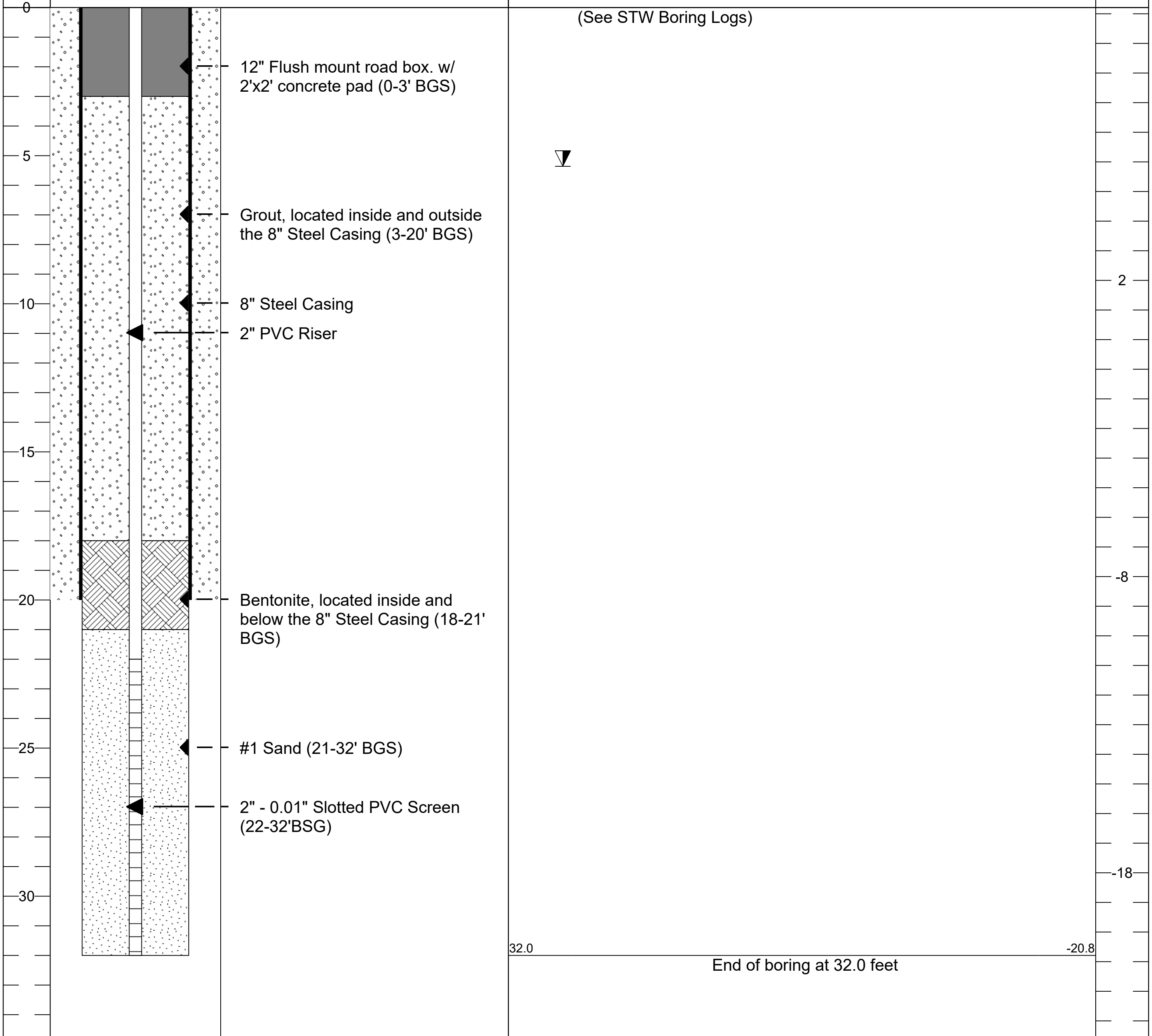
CLIENT	BASF	**PROJECT NAME**	BASF Cranston
PROJECT NUMBER	172-818	**PROJECT LOCATION**	Cranston, RI
DATE STARTED	09/30/2019	**DATE COMPLETED**	09/30/2019
GROUND ELEVATION	11 ft	**BACKFILL**	
SAMPLING CONTRACTOR	Geosearch, Inc.	**LATITUDE**	41.765936
LONGITUDE	-71.411906	**SAMPLING METHOD**	10-1/4" + 6-1/4" HSA
CEC REP	Dylan Lundgren	**CHECKED BY**	Glen Cote
NOTES	Double Cased Well		

WATER LEVELS
- AT END OF SOIL SAMPLING:
- AT END OF CORING:
- 24 HRS AFTER DRILLING: 10/02/2019 5.1 ft / Elev 6.1 ft

DEPTH (ft)	WELL DIAGRAM	MATERIAL DESCRIPTION	ELEVATION (ft)
0		(See STW Boring Logs)	
32.0		End of boring at 32.0 feet	-20.8



Civil & Environmental Consultants, Inc.
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Raynham, MA 02767

BORING NUMBER TW-1A

Client: BASF

Project Name: BASF Cranston

Project Number: 172-818

Project Location: Cranston, RI

Date Started: 09/23/2019

Date Completed: 09/23/2019

CEC Field Representative: Glen Cote

Log Checked By: Glen Cote

Ground Elevation:

Casing Elevation: NA

Latitude:

Longitude:

Drilling Contractor: Geosearch, Inc.

Driller: Michael DeAmicis

Drilling Method: Direct Push

Core Size: NA

Backfill: with Bentonite

Borehole Diameter: 2.00 in

Well Installed: None

Stickup: None

Key: NA

Outer Casing: NA

Monitoring Equipment:

Development Method: NA

Results: NA

Yield: NA

Water Levels

At Drilling: NA

End of Drilling: NA

After Drilling: NA

Temporary Well: NA

Permanant Well : NA

Notes:

NA - Not Available; bgs - below ground surface; amsl - above mean sea level

Civil & Environmental Consultants, Inc.
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BORING NUMBER TW-1A

CLIENT BASF

PROJECT NAME BASF Cranston

PROJECT NUMBER 172-818

PROJECT LOCATION Cranston, RI

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	RECOVERY % (RQD)	BLOWS COUNTS (N VALUES)	PID (PPM)	WELL DIAGRAM
0		Discrete Sampling (started collecting samples at 30' BSG)				
5		▽				
10						
15						
20						
25						
30	30.0	Gray, SILT, Little Fine Sand, and Clay, Wet				
			43	--	0.2	
35						

(Continued Next Page)

Civil & Environmental Consultants, Inc.
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BORING NUMBER TW-1A

CLIENT BASF
PROJECT NAME BASF Cranston
PROJECT NUMBER 172-818
PROJECT LOCATION Cranston, RI

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	RECOVERY % (RQD)	BLOWS COUNTS (N VALUES)	PID (PPM)	WELL DIAGRAM
	38.0	Gray, SILT, Little Fine Sand, and Clay, Wet	50	--	0.0	
40	40.0	Gray, Medium to Coarse Grained, GRAVEL, Trace Silt, and Fine Sand, Wet				
45	45.0	Gray, Fine Grained, SAND AND SILT, Trace Clay, Wet	30	--	0.1	
50	50.0	Gray, Fine Grained, SAND, Little Silt, Trace Clay, Wet	53	--	0.0	
55		End of boring at 50.0 feet				
60						
65						
70						

Civil & Environmental Consultants, Inc.
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BORING NUMBER TW-4A

Client: BASF

Project Name: BASF Cranston

Project Number: 172-818

Project Location: Cranston, RI

Date Started: 09/23/2019

Date Completed: 09/23/2019

CEC Field Representative: Glen Cote

Log Checked By: Glen Cote

Ground Elevation:

Casing Elevation: NA

Latitude:

Longitude:

Drilling Contractor: Geosearch, Inc.

Driller: Michael DeAmicis

Drilling Method: Direct Push

Core Size: NA

Backfill: with Bentonite

Borehole Diameter: 2.00 in

Well Installed: None

Stickup: None

Key: NA

Outer Casing: NA

Monitoring Equipment:

Development Method: NA

Results: NA

Yield: NA

Water Levels

At Drilling: NA

End of Drilling: NA

After Drilling: NA

Temporary Well: NA

Permanant Well : NA

Notes:

NA - Not Available; bgs - below ground surface; amsl - above mean sea level

Civil & Environmental Consultants, Inc.
31 Bellows Road
Raynham, MA 02767

BORING NUMBER TW-4A

CLIENT BASF | **PROJECT NAME** BASF Cranston

PROJECT NUMBER 172-818 | **PROJECT LOCATION** Cranston, RI

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	RECOVERY % (RQD)	BLOWS COUNTS (N VALUES)	PID (PPM)	WELL DIAGRAM
0		Discrete Sampling (started collecting samples at 30' BSG)				
5		▽				
30.0		Gray, SILT, Some Sand, Trace Clay, Wet	57	--	0.4	
34.0		Gray, Medium to Coarse Grained, SAND, Some Medium to				

(Continued Next Page)

Civil & Environmental Consultants, Inc.
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BORING NUMBER TW-4A

CLIENT BASF **PROJECT NAME** BASF Cranston

PROJECT NUMBER 172-818 **PROJECT LOCATION** Cranston, RI

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	RECOVERY % (RQD)	BLOWS COUNTS (N VALUES)	PID (PPM)	WELL DIAGRAM
35.0		Gray, Medium to Coarse Grained, SAND, Some Medium to Coarse Gravel, Wet				
		Gray, Fine to Coarse Grained, GRAVEL, Some Coarse Sand, Wet	--	--	1.2	
40.0		Fine Grained, SAND AND SILT, No Sample Recovered	--	--		
45.0		End of boring at 45.0 feet				

Depth scale: 40, 45, 50, 55, 60, 65, 70

Civil & Environmental Consultants, Inc.
31 Bellows Road
Raynham, MA 02767

BORING NUMBER BT-3

Client: BASF

Project Name: BASF Cranston

Project Number: 172-818

Project Location: Cranston, RI

Date Started: 07/18/2019

Date Completed: 07/18/2019

CEC Field Representative: Dylan Lundgren

Log Checked By: Glen Cote

Ground Elevation:

Casing Elevation: NA

Latitude:

Longitude:

Drilling Contractor: Drilex Environmental

Driller: Dave Bleen

Drilling Method: Direct Push

Core Size: NA

Backfill: with Bentonite

Borehole Diameter: 2.00 in

Well Installed: None

Stickup: None

Key: NA

Outer Casing: NA

Monitoring Equipment:

Development Method: NA

Results: NA

Yield: NA

Water Levels

At Drilling: NA

Permanant Well : NA

End of Drilling: NA

After Drilling: NA

Temporary Well: NA

Notes: PID reading not collected

NA - Not Available; bgs - below ground surface; amsl - above mean sea level

Civil & Environmental Consultants, Inc.
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Raynham, MA 02767

BORING NUMBER BT-3

CLIENT BASF **PROJECT NAME** BASF Cranston

PROJECT NUMBER 172-818 **PROJECT LOCATION** Cranston, RI

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	ELEVATION (ft)	SAMPLE INTERVAL & ID NUMBER	RECOVERY % (RQD)	PID (PPM)
0		Discrete Sampling (started collecting samples at 10' bgs)	0			
5						
10	10.0 ft	Black, SILT, Little Fine Sand, Trace Fine Gravel, Wet	-10			
	11.0 ft	Dark Gray to Light Gray, Fine Grained, SAND, Trace Silt, Trace Medium to Coarse Gravel, Wet, Very slight odor		BT-3 (10-15')	50	--
15	15.0 ft	End of boring at 15.0 feet				
20			-20			
25						

Civil & Environmental Consultants, Inc.
31 Bellows Road
Raynham, MA 02767

BORING NUMBER BT-4

Client: BASF

Project Name: BASF Cranston

Project Number: 172-818

Project Location: Cranston, RI

Date Started: 07/18/2019

Date Completed: 07/18/2019

CEC Field Representative: Dylan Lundgren

Log Checked By: Glen Cote

Ground Elevation:

Casing Elevation: NA

Latitude:

Longitude:

Drilling Contractor: Drilex Environmental

Driller: Dave Bleen

Drilling Method: Direct Push

Core Size: NA

Backfill: with Bentonite

Borehole Diameter: 2.00 in

Well Installed: None

Stickup: None

Key: NA

Outer Casing: NA

Monitoring Equipment:

Development Method: NA

Results: NA

Yield: NA

Water Levels

At Drilling: NA

End of Drilling: NA

After Drilling: NA

Temporary Well: NA

Permanant Well : NA

Notes:

NA - Not Available; bgs - below ground surface; amsl - above mean sea level

Civil & Environmental Consultants, Inc.
31 Bellows Road
Raynham, MA 02767

BORING NUMBER BT-4

CLIENT BASF

PROJECT NAME BASF Cranston

PROJECT NUMBER 172-818

PROJECT LOCATION Cranston, RI

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	ELEVATION (ft)	SAMPLE INTERVAL & ID NUMBER	RECOVERY % (RQD)	PID (PPM)
0		Discrete Sampling (started collecting samples at 25' bgs)	0			
5						
10			-10			
15						
20			-20			
25						

(Continued Next Page)

Civil & Environmental Consultants, Inc.
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Raynham, MA 02767

BORING NUMBER BT-4

CLIENT BASF
PROJECT NAME BASF Cranston
PROJECT NUMBER 172-818
PROJECT LOCATION Cranston, RI

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	ELEVATION (ft)	SAMPLE INTERVAL & ID NUMBER	RECOVERY % (RQD)	PID (PPM)
25.0 ft		Gray, Fine Grained, SAND, Some Silt, Little Clay, Wet, Slight solvent odor			53	2.0
30 (30.0 ft)		Gray, Fine Grained, SAND, Little Silt, Wet, No odor	-30	BT-4 (30-35')	60	0.0
35 (35.0 ft)		End of boring at 35.0 feet				
40			-40			
45						
50			-50			

APPENDIX F
STANDARD OPERATION PROCEDURES

172-818 - BASF Cranston, Rhode Island

Standard Operating Procedure (SOP)			
Job:	Persulfate Sock Preparation - 2 People		
PREPARED BY: Glen Cote	**DATE CREATED:** 11/13/2019		
REVIEWED BY: Steve Maxwell	**DATE UPDATED:** 5/1/2020		
Required PPE:	1. Neoprene, Polyvinylchloride, or Natural Rubber Gloves 2. Cut-Resistant Gloves 3. Tyvek Coveralls 4. Chemical Resistant Aprons 5. Chemical Goggles 6. Boot Covers 7. Full-face Respirator	**Additional Materials:**	1. Eye wash/Eye Wash Station 2. Vinegar 3. Fire Extinguisher 4. First Aid Kit 5. 5-Gallons Fresh Water 6. Polyethylene Sheeting 7. Chemical Resistant Containers 8. Socks-4"x41" non-woven polyethylene fabric, needle punched. 9. Plastic 55-gallon drums 10. Plastic sealable tote/containers 11. 5-gallon buckets w/lids 12. Paint mixer 13. Zip-ties 14. Fans 15. Funnel 16. Generator (on-site)
Project Contacts:	Project Manager: Steve Maxwell – 215 514-9603 Site Safety Manager: Glen Cote – 617 838-9600 Project Principal: Jon Kitchen – 508 326-8727 Corporate H&S: Keith Robinson – 614 364-0704 Joe Guarnaccia: BASF Client – 732 762-4743		
Emergency Contacts:	Ambulance: 911 Raynham Fire Station: 911 Raynham Police Department: 911 Morton Hospital 88 Washington St, Taunton, MA 02780		

This Standard Operation Procedure (SOP) describes the method to prepare the socks. The socks are to be prepared either off-site in the bay of the warehouse or on-site.

1. Order chemicals from Peroxychem and have them delivered to the Warehouse.
    a. 7, 55 pound bags of KP
    b. 1 50 pound bags of Lime.
        i. Arrange for the contractor with the DOT Hazardous Materials Transportation license to move the materials from the warehouse to the Site.
2. Observe the work area and preparation.
    a. Assess work area for trip hazards, wet floor and overhead hazards. Move potential hazards out of the work area. Place a large piece of 6-mil poly sheeting on the floor of the work area to capture spills.
        i. On-site work shall be completed on a level and flat surface.
3. Create a well-ventilated area to reduce the risk of dust exposure.
    a. Off-site Inside Work Area - Open overhead door of the warehouse and set up two ventilation fans (one in back (away from overhead door) of work zone and one in front (toward overhead door) of work zone) to move and evacuate air/dust particles from the work zone, and exhausting it out the overhead door.
    b. On-Site Work Area - Set up ventilation fans in the same manner on-Site. Exhaust the air flow to blow downwind (with the wind flow direction).
    c. On-Site Work Area – Bring a generator to the Site to power the ventilation fans.
        i. Fuel generator before arriving on Site.
        ii. If a fuel can is necessary, place fuel can for generator in secondary containment and fill generator over secondary containment.
4. Don PPE, including Tyvek, chemical aprons, boot covers, gloves and a respirator.
5. Measure Chemicals (Potassium Persulfate (KP) and Lime)
    a. Open bags of KP and Lime in a manner that they can be resealed.
    b. Ensure chemicals are kept away from sources of water.
    c. Add a mixture of 78% Potassium Persulfate and 22% Lime by volume using measuring cups to a sealable 5-gallon pail (mark out increments for each quarter of pail volume by drawing a line around the exterior of the bucket with a black sharpie marker.
        i. Scoop each chemical and slowly pour the material out of the measuring cup close to the bottom to avoid dust generation.
        ii. Leave enough space in the bucket so that the contents can be mixed (at least ¼ headspace in the bucket).
        iii. Tightly seal and secure the 5-gallon bucket with the lid.
        iv. Shake vigorously, tumble, roll and/or use a paint mixer to homogenize the chemicals together. If using a paint mixer, first drill a small hole through the middle of the lid and extend the shaft of the mixer through the hole. Use a bushing at the hole to reduce potential dust emissions coming out from the bucket.
        v. Mix chemicals for at least three minutes to ensure a complete blend.
        vi. Allow at least 5 minutes for the dust to settle in the bucket before removing the lid.
6. Transfer Mixed Chemicals into the Socks
    a. Open the lid of the bucket near the ventilation fan so that dust will flow forward and exhaust outside/downwind. Be sure to stand up-wind of the bucket. The socks should also be filled at this location to minimize suspended dust in the breathing zone during the building process.
    b. Tie a knot at the bottom of the sealed/sewn end of the sock and secure with a zip-tie. This will allow a place for the string to connect to when stringing the socks in the field for deployment.
    c. One person shall place the bottom of the funnel near the bottom of the empty sock while the second person uses a scoop to slowly transfer the chemicals from the bucket into the funnel.

d. As the sock fills, continuously move the funnel a couple inches above the top of the chemicals until the mixture is approximately 6 inches from the top of the sock. This allows room for the top of sock to be tied. Each completed sock will be approximately 3 feet long.

e. Tie top of the filed sock and secure the knot with a zip-tie.

f. Place finished sock into a sealable and properly labeled plastic 55-gallon drum.

    ii. Inside Work Area – Drums will need to be transported to the Site by personnel with a DOT Hazardous Materials Transportation license.

    iii. On-Site Work Area – Temporarily store drums containing the new socks in shed.

7. Clean Up Procedure - ***Do not remove PPE until chemicals and all sources of dust have been sealed and removed from the area.***

a. Reseal and place all partially used bags of lime and KP in separate sealable plastic totes or plastic 55-gallon drums to prevent accidental spillage.

    i. Do not store KP and Lime adjacent to each other.

    ii. Do not store in wet, or areas that could become potentially wet.

b. Inside Work Area - Roll up 6-mil poly sheeting, consolidate disposable tainted materials and place in a trash bag. Dispose these materials in trash.

c. On-Site Work Area – Roll up 6-mil poly sheeting, consolidate disposable tainted materials and place in a trash bag. Transport the trash back to the CEC warehouse for disposal in the trash.

d. Decontaminate and remove PPE. Place disposable PPE in trash bag and dispose in trash. Thoroughly clean reusable PPE and return to storage.

172-818 - BASF Cranston, Rhode Island

<table>
<tr><th colspan="4">Standard Operation Procedure (SOP)</th></tr>
<tr><td>Job:</td><td colspan="3">Installation of Alkaline Activated Potassium Persulfate (AAKP) Socks and DNAPL Absorbents/Weigh Socks - 2 People</td></tr>
<tr><td>PREPARED BY:
Glen Cote</td><td colspan="2">DATE CREATED:
11/13/2019</td><td></td></tr>
<tr><td>REVIEWED BY:
Steve Maxwell</td><td colspan="3">DATE UPDATED:
4/13/2020</td></tr>
<tr><td>Required PPE:</td><td>1. Neoprene, Polyvinylchloride, or Natural Rubber
2. Gloves
3. Cut-Resistant Gloves
4. Tyvek Coveralls
5. Chemical Resistant Aprons
6. Chemical Goggles
7. Face Shield
8. Boot Covers
9. N-95 Dust Mask (minimum)</td><td>Additional Materials:</td><td>1. Eye wash/Eye Wash Station
2. Vinegar
3. Fire Extinguisher
4. First Aid Kit
5. 5-Gallons Fresh Water
6. Polyethylene Sheeting
7. Chemical Resistant Containers</td></tr>
<tr><td>Project Contacts:</td><td colspan="3">Project Manager: Steve Maxwell – 215 514-9603
Site Safety Manager: Glen Cote – 617 838-9600
Project Principal: Jon Kitchen – 508 326-8727
Corporate H&S: Keith Robinson – 614 364-0704
BASF Client: Joe Guarnaccia– 732 762-4743</td></tr>
<tr><td>Emergency Contacts:</td><td colspan="3">Ambulance: 911
Cranston Fire Station 2: 911
Cranston Police Department: 911
Rhode Island Hospital
593 Eddy St. Providence, RI 02903</td></tr>
</table>

This Standard Operation Procedure (SOP) describes the method of preparing the socks for deployment in the field, as well as absorbents if required, and monitoring the depletion rates of the socks and recovery of product.

1) Observe the work area and preparation.
    a. Assess work area for trip hazards and uneven surfaces. Place a large piece of 6-mil poly sheeting on the ground of the work area to capture spills. Set up the pop-up canopy if weather is unfavorable (i.e. rain, snow, sunny, etc.). Secure pop-up canopy to ground to keep it in-place during windy field events.
2) Gauge the water level in the treatment well using the decontaminated oil/water interface probe. Record the data on the site-specific field form.
3) Attach prepared sock to the stringer.
    a. Check the work area for water on the plastic sheeting, replace sheeting if wet.
    b. Remove 3 new prefabricated socks from the plastic 55-gallon storage drum and stage on the plastic sheeting.
    c. Zip-tie the socks to the string at the bottom, middle, and top of each sock.
    d. Connect the handle to each stringer and verify labeling (i.e. shallow and deep).
    e. Attach a 0.25-inch LDPE groundwater sampling tube to the shallow stringer using zip-ties. The intake of the tubing is to be located between the top sock and the second sock of the deeper stringer, which approximately in the middle of the well screen.
    f. If DNAPL absorbent material is necessary, attach a rigid 3-foot section of piping/PVC dowel to the absorbent using zip-ties to keep it straight in the well. Tie with string and zip-tie the absorbent to the bottom of the deep stringer. This is to be performed while the deep stringer is being constructed.
    g. 2 people are to install one stringer at a time; deep goes in first, then shallow. The deep stringer must extend to the bottom of the well, then lower the shallow stringer until is stops, then pull up about 1-foot. Tie the string for each stringer to separate handles and allow the socks to be suspended in the water column.

(see attached photos for an example of stringer and absorbent assembly)

To gauge and monitor the AAKP sock depletion and the amount of recovered product, follow these procedures:

4) Use fish scale to weigh each AAKP sock stringer that consists of 3 socks tied in tandem (2 per well – one deep and one shallow stringer) and record data on the site-specific field form (attached).
    a. Keep the socks in the wells while weighing, do not remove until it's time to remove/replace socks.
    b. If stringer weight is 1.5 lbs. or less, pull sock and check KP in the groundwater.
    c. If KP is less than 15 mg/L, proceed to step 5 to change socks on the stringer. If KP is >15mg/l, proceed to step 6 to clean-up.
5) Remove each stringer consisting of 3 socks from the well.
    a. Remove one stringer at a time and place spent socks into the plastic 55-gallon drum.
    b. Absorbents are to be disposed in the plastic 55-gallon drum. Do not use metal drums, fore the oxidizer will corrode the metal and the drum will fail.
    c. Gauge depth to water, depth to bottom, and for presence of product using a decontaminated oil/water interface probe. Check the interface probe for product and if product is present, then use a bailer to measure the product thickness. Make sure the bailer falls to the bottom of the well. It should be noted that the interphase probe has not detect the product within these wells for some reason, therefore measure the thickness of product captured in the bailer. Note the condition of the absorbent for saturation and staining. Product/groundwater recovered and the absorbents are to be transferred into separate plastic 55-gallon drums.

d. Check for sediment at the bottom of the well by measuring the depth to bottom and compare to total depth of the well length when it was initially installed (total depth to bottom is approximately 32').
e. If well depth is at least 1-foot less than the installation depth, then sediment has built up in the well and should be removed using a peristaltic (or equivalent) pump.
    i. Use the pump and 0.5 inch LDPE tubing to evacuate the sediment in the bottom of each well as necessary. All recovered sediment (i.e. silt and/or solids from socks) is to be transferred into a plastic 55-gallon drum.

6) Clean-Up/Drum Storage Area
    a. Prepare/evaluate the drum disposal area. The drums of hazardous water materials are to be stored on a pallet, and in the designated waste storage area located adjacent to the stone pad. This will allow for drums to be picked-up. Hazardous waste material drums must be collected within 90-days of their generation date.
    b. Roll-up 6-mil plastic sheeting, place in heavy-duty construction bag and dispose in trash. There are no dumpsters or disposal receptacles on-Site, therefore trash will need to be transported to office for disposal in the municipal dumpster.
    c. Place spent materials (i.e. tubing, bailers, PPE, etc.) into a heavy-duty construction bag and dispose in trash.
    d. Place extra unused socks in a designated plastic 55-gallon drum and inside the shed. Label drum with the oxidizer placard/label.
    e. Verify the shed is not leaking and that the oxidizer placard/label located on the exterior of the shed is secured.
    f. Seal all drums and label with Hazardous Waste stickers. Fill out the fields on the sticker and secure the label to the drum. Make sure the drum is dry when applying the sticker.
    g. Secure all on-site equipment and supplies in the shed.
    h. Secure and lock the gate.